Electrical Engineering

Registered U. S. Patent Office

for July 1938—

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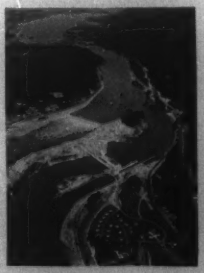
The Cover

Bonneville dam on the Columbia River, which may be visited by those attending the AIEE 1938 Pacific Coast convention (see pages 295–7)

Brubaker Aerial Surveys



High Lights

Printing Telegraph for Way Wires. Most commercial telegraphic trunk circuits have been operated by printing telegraph methods for several years, but Morse-code operation generally has been used on way wires. New equipment and methods for operating way wires by printing telegraph include a polar simplex system, a neutral way-wire system, a calling-bell system, and a multistation customers' printer circuit that provides secrecy of communication by preventing the connection of more than one customer's printer to the line at the same time (*Transactions pages 365–72*).

Amplifier for Measurements. Modern electric instruments are reliable and accurate, but for some applications their energy consumption is undesirably large when connected directly into the circuit. For an a-c network analyzer, which requires instruments having a high degree of accuracy with extremely small energy consumption, a stabilized vacuum-tube amplifier to be connected between the analyzer circuit and the indicating instrument has been devised (*Transactions pages 379–84*).

Phanotron Rectifiers. In areas where electric utility companies have discontinued direct current in favor of a-c distribution, a-c elevator equipment may have to be substituted for existing d-c apparatus; the alternative is to provide a converter for supplying direct current to the existing equipment from the a-c mains. The use of phanotron rectifiers for this purpose has some advantages (*Transactions pages 385–90*).

Pacific Coast Convention. The scenic beauty of the Pacific Northwest awaits those who will combine their vacation trips with attendance at the AIEE 1938 Pacific Coast convention, to be held in Portland, Ore., August 9–12. Convention features include an excellent technical program, an all-day inspection trip to the Bonneville dam, and a variety of sports competitions (*pages 295–7*).

Railway Circuit Breaker. Railway trolley service imposes severe duty on circuit breakers because of the frequency of short-circuit operations. A breaker operating on the so-called impulse principle has been built to interrupt 65,000 amperes at 15,000 volts in one cycle, and is expected to handle 50 operations without internal inspection or change of oil (*Transactions pages 359–64*).

Economic Status. Monetary returns in the profession of engineering compare favorably with those in other professions, according to an analysis of data obtained from more than 50,000 engineers. Personal qualities, rather than technical education, are believed to influence the separation of engineers into various salary levels (*pages 281–5*).

The Engineering Library. The engineering library may be regarded as a laboratory; like other laboratories, it is a place for study and research. According to one authority, library research indubitably is the proper first step in any investigation and may save much time-consuming expensive experimental work (*pages 291–4*).

New Type of Vacuum Seal. A new type of lead-in structure for airtight, gastight, and oiltight chambers employs porcelain bushings sealed to metal by means of a special glass. The method of making the seal is said to be simple, requiring no special skill or elaborate equipment (*Transactions pages 373–8*).

High-Voltage Fluorescent Tubes. A recent innovation in high-voltage gaseous-discharge tubes—the use of fluorescent materials coated on the insides of the tubes for producing light of different colors—eventually may change the whole complexion of advertising and architectural lighting. (*pages 286–90*).

Transients. Illustration of transients on transmission lines by motion pictures has been found to be an educational aid; drawings for the films and three-dimensional models were prepared from data for d-c transients obtained experimentally on an artificial line (*Transactions pages 391–400*).

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New Products	(See advertising section)
Employment Notes	(See advertising section)
Officers and Committees	(For complete listing see pages 1217–21 September 1937 issue)

Board of Directors Report. The annual report of the AIEE board of directors to the membership, for the year ending April 30, 1938, appears in full in this issue. It contains reports of the various committees and the usual financial tabulations (*pages 305–15*).

Summer Convention. At the AIEE 1938 summer convention, just concluded at Washington, D. C., as this issue goes to press, new officers were elected and the enactment of constitutional amendments was announced (*pages 303–04*).

Lenox Meeting. Power-system operating problems and industrial applications featured the technical program of AIEE North Eastern District meeting held at Lenox, Mass., May 18–20. More than 400 registered (*pages 298–302*).

Pamphlet Papers Available. A limited supply of pamphlet copies of papers presented at recent AIEE conventions and District meetings is available; the list is accompanied by a convenient order form (*page 328*).

Coming Soon. In addition to articles and papers mentioned in the "Coming Soon" items in previous recent issues, the following are now undergoing preparation for early publication: an article reviewing the status of rural electrification in England; a paper discussing resonant nonlinear control circuits and their applications, by W. T. Thomson (A'37); and a paper analyzing the effect of amortisseur windings on overvoltages caused by unbalanced short circuits on electric-power systems, by Edith Clarke (M'33) C. N. Weygandt (A'37) and Charles Concordia (M'37).

DISCUSSIONS

Appearing in this issue are discussions of the following previously published papers:

Electrical Machinery

Alternator Short-Circuit Currents Under Unsymmetrical Terminal Conditions—Miller and Weil	401
D-C Machine Stray-Load-Loss Tests—Siegfried	401
Unsymmetrical Short Circuits on Water-Wheel Generators Under Capacitive Loading—Wagner	406
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Instruments and Measurements

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Power Transmission

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Statements and opinions given in articles and papers appearing in ELECTRICAL ENGINEERING are the expressions of contributors, for which the Institute assumes no responsibility. Correspondence is invited on all controversial matters. ¶ Subscriptions—$12 per year to United States, Mexico, Cuba, Porto Rico, Hawaii, Philippine Islands, Central and South America, Haiti, Spain, Spanish Colonies; $13 to Canada; $14 elsewhere. Single copy $1.50. ¶ Address changes must be received by the fifteenth of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge. ¶ ELECTRICAL ENGINEERING is indexed annually by the Institute, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index*; abstracted monthly by *Science Abstracts* (London).

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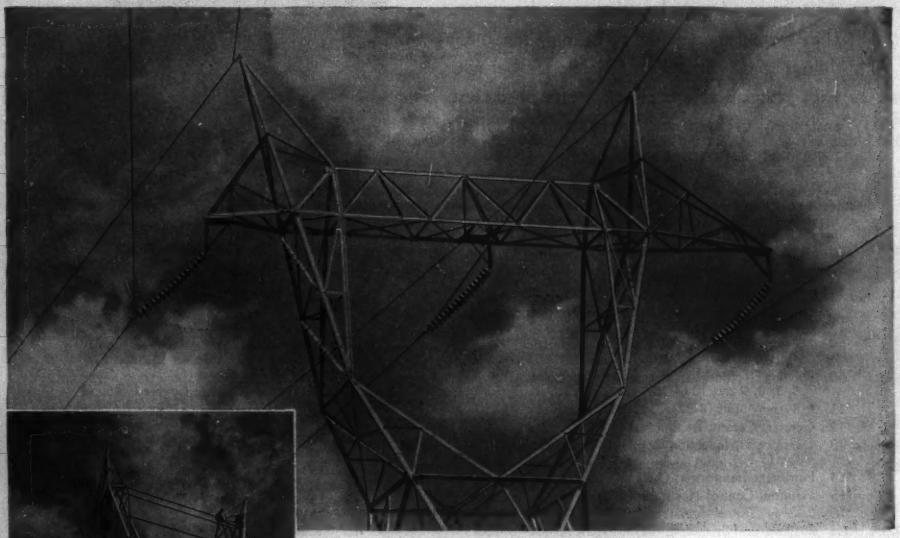

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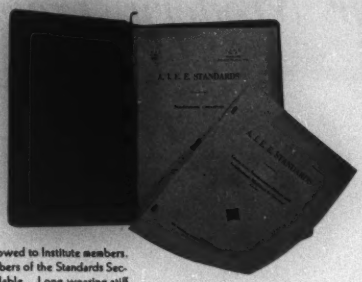
UNITED STATES STEEL

A.I.E.E. STANDARDS

THE Standards of the American Institute of Electrical Engineers now comprise forty-seven sections on electrical machinery and apparatus. They are chiefly devoted to defining terms, conditions, and limits which characterize behavior, with special reference to acceptance tests, and many of them are recognized officially as American Standards.



The Standards available are listed below, together with prices. A discount of 50% is allowed to Institute members. Such discount is not applicable on extra copies unless ordered for other members. Numbers of the Standards Sections should be given when ordering. A binder (illustrated above) for standards is available. Long wearing stiff covers, resembling leather, lettered in gold. Price $1.75 net.

(Figures in Parentheses Give Dates of Latest Editions)

No. 1	General Principles Upon Which Temperature Limits Are Based in the Rating of Electrical Machinery (4-25)	$0.20
4	Measurement of Test Voltage in Dielectric Tests (5-28)	.30
*C50	Rotating Electrical Machinery, Supersedes Nos. 5, 7, 8, 9 and 10 (4-36)	1.30
*11	Railway Motors (4-37)	.50
*12	Constant Current Transformers (1-34)	.30
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*18	Capacitors (6-34)	.20
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20	Air Circuit Breakers (5-30)	.30
22	Disconnecting and Horn Gap Switches (7-25)	.30
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*38	Electric Arc Welding Apparatus (1-34)	.40
*39	Electric Resistance Welding Apparatus (1-34)	.30
*41	Insulators (3-30)	.30
*42	Symbols for Electrical Equipment of Buildings (12-23)	.20
45	Recommended Practice for Electrical Installations on Shipboard (10-30)	1.50
*46	Hard Drawn Aluminum Conductors (6-27)	.20
*60	Specifications for Tinned Soft or Annealed Copper Wire. (See No. 61 for price.)	
*61	Specifications for Soft or Annealed Copper Wire. (Nos. 60 and 61 published as one pamphlet) (9-28)	.30
*C8.4	Specifications for 30 Per Cent Rubber Insulation for Wire and Cable for General Purposes (1936)	.20
*C8.5	Specifications for Cotton Covered Round Copper Magnet Wire. (See C8.7 for price.)	
*C8.6	Specifications for Silk Covered Round Copper Magnet Wire. (See C8.7 for price.)	
*C8.7	Specifications for Enameled Round Copper Magnet Wire. (C8.5, 8.6 and 8.7 published as one pamphlet) (1936)	.30
*C8.11	Code Rubber Insulation for Wire and Cable for General Purposes (1936)	.20
*C8.12	Cotton Braid for Insulated Wire and Cable for General Purposes (1935)	.20
*C8.16	Tree Wire Coverings (1936)	.20
*C8.17	Class OA 30 Per Cent Rubber Insulation for Wire and Cable for General Purposes (1936)	.20
*C8.18	Weather Resistant Wire and Cable URC Type (1936)	.20
*72	Specifications for Weatherproof Wires and Cables. (See No. 73 for price.)	
*73	Specifications for Heat-Resisting Wires and Cables. (Nos. 72 and 73 published as one pamphlet) (9-32)	.20
100	Recommendations for the Operation of Transformers (6-30)	.20
500	Test Code for Polyphase Induction Machines (8-37)	.50
	Total Cost of Complete Set	$14.70

* *Approved as American Standard.*

SECTIONS IN PREPARATION

Six such sections are now available in report form for purpose of criticism, and copies will be sent without charge upon request. These sections are as follows:

No. 6	Mercury Arc Rectifiers.	40	Electrical Recording Instruments.
25	Fuses Above 600 Volts.	—	Test Code for Transformers.
501	Test Code for D-C Machines.	—	Test Code for Synchronous Machines.

American Institute of Electrical Engineers — **33 West 39th Street, New York**

President Harrison Emphasizes the Institute's Fundamental Responsibilities*

IN presenting this talk, I am fulfilling a provision in the constitution of the Institute which says that the president ". . . shall deliver an address at an annual convention." At the outset I want to express for the other officers and directors, and for myself, appreciation and gratitude for the enormous amount of voluntary effort put forth by the members on behalf of the Institute. I want especially to commend Mr. Henline and his associates on the headquarters staff for their effective and constructive work during the past year, and for the gracious manner in which they have met the demands of officers and members alike.

Along with the honor of the office and the privilege to serve, the president has responsibilities to the Institute. One of these takes form in an obligation to tell of any impressions he may hold as a result of experience and association with the members and officers throughout the various Sections.

Having enjoyed visiting with some 40-odd Sections, embracing more than 70 per cent of the membership, and having been exposed to their views, I do hold certain impressions which I think pertinent to touch upon at this time. These impressions have to do with the extent to which the Institute should be a force in the determination of considerations which lead up to the use of public funds in fields which heretofore have been largely developed by private initiative.

In this I am mindful of the concern with which many in the profession view—and not without merit—the increasing participation of Government agencies in commercial enterprises, particularly in fields already adequately served. Perhaps an important transition is under way. We well may be at the start of a long-range cycle of change. Certainly it would be a misconception to assume that the present state of affairs is merely the result of a statute, a political situation, or a business cycle. Looking at the Institute in long-range perspective and with these things in mind I am confident that we best can serve the interests of the public, the industry, the profession, and the Institute itself by continuing to follow the broad ground rules upon which the Institute was founded, and which are stated in its constitution in these clear words: "Its objects shall be the advancement of the theory and practice of electrical engineering and of the allied arts and sciences and the maintenance of a high professional standing among its members." These simple words express the whole idea back of the Institute and its activities. The distinguished record of service attests to the soundness of these principles.

Considering this whole matter broadly, we must realize that every conceivable social, economic, and political philosophy is to be found in our membership. It must be clear, too, that only the united and unselfish effort of the membership has made the Institute the force it is. To destroy this unity, which in my judgment would be the case were the Institute to enter on a national basis a field so full of conflict of thought and of economic interest, and so sacred to the individual as are his social, economic, and political views, would be to sacrifice the fulfillment of the principles for which the Institute was founded.

From the time of its first technical meeting (at Philadelphia in October 1884) up to the present, every electrical development of substantial importance has been described and discussed in the Institute's meetings and publications. We can get a vivid picture of the value of these developments by imagining for a moment what would have to be done over again to bring us back to our present state if the knowledge in the many volumes which constitute the printed record of our proceedings and the things which this knowledge has made possible were, by some disaster, to disappear. It would, for example, be necessary to develop the whole art of a-c transmission and distribution, of electric traction, of radio and modern wire communication, and almost the whole arts of electric lighting and other means of power utilization.

It would be necessary again to bring forth the technical and theoretical genius of men like Edison, Elihu Thomson, Steinmetz, Kennelly, Pupin, Campbell, Sprague, Lamme, and many others; and the genius for adaptation and application of men like Westinghouse, Dunn, Carty, Rice, and others, all of whom are, or in their lifetimes were, interested and active members of the Institute who contributed most generously to the fulfillment of its objectives. No one can say that if there had been no AIEE these things would not have been done or that these men would not have applied their great talents for the good of mankind either as they did or in some equivalent way. But neither would anyone deny that the Institute actually was a vital and constructive influence in shaping events and careers as we know them today.

The Institute, with this proud record and background of service, will continue to be a living influence in the development and application of the electrical sciences and arts. The inspiration and knowledge gained from its meetings and discussions and publications, the stimulation and encouragement of the prompt recognition and honors awarded for noteworthy achievement, the opportunities it affords for the prompt announcement and critical examination under appropriate auspices of new technical developments and ideas, always will be essential elements in the progress of electrical engineering.

The importance and degree of influence of the Institute's job depends upon the increase in the knowledge of the electrical sciences and the electrical arts and the

* Notes used by Retiring President W. H. Harrison in speaking before the summer convention general session, Washington, D. C., June 22, 1938.

extent of their application to the service of man, and seems clearly to me to be independent of the forms of social and business organization which administer their application.

Certainly there is not now, nor is there apt to be in the future, any dearth of things to do that are strictly within our province. The frontiers of knowledge of electrical science and arts—technical and commercial—are expanding constantly and there is nothing to indicate they will not continue to expand. In our unimaginative moments we sometimes may doubt this. Sometimes it may seem to us that nothing is possible in the future that can be compared with the opportunities and achievements of earlier days. As a matter of fact, this is a common characteristic of every generation. History records a succession of prophesies wherein little or no hope is offered for the "future." Such prophecies and beliefs are as groundless and false now as they so obviously were throughout all the past.

Even during these last few years of depressed business, many noteworthy advances have been discussed at Institute meetings. At this summer convention, for example, papers are being presented that describe the practical application of the principles of fluorescence in the production of light. Likewise, there has been a good deal of work and progress in the use of electronic devices in power application. Within just the last year or two we have been told about interesting and important discoveries concerning natural lightning and about experiments on an imposing scale with artificial lightning. Also at this convention, as well as at last winter's convention, papers were presented describing new instrumentalities that will have a far reaching effect on the future development of the telephone art. Television is another new development about which we are learning more and more. This development has a romantic and even fantastic aspect that has been exceeded in degree by few, if any, of the numerous developments about which the Institute has been told in the past.

These are but a few examples. In every branch of the industry there are similar concrete indications of a vigorous and fascinating future. And if at the moment each of us cannot put his finger on a definite example in his own special branch of the art, we all at least can agree that we have not yet arrived at perfection in any field and each of us without much trouble can point to important parts of our work that remain undone, perhaps because we don't know how to do them.

We may be sure that man's inventive spirit and curiosity will find ways to do these things, or alternative things that will be so much different and better that we do not have the boldness even to imagine them. In this field of expanding activity the Institute has before it a continually increasing opportunity for service to the profession and to mankind. We can be proud of the part the Institute has played in the development of an industry which, in an era of free enterprise, has given this nation of ours commodities and services that are more extensively used, are better in quality, and are lower in price than anywhere else in the world. With six per cent of the world's population and five per cent of its area, the United States uses a third of the world's electric energy and half of its communication services.

We now are in a period of change—in social and political organization, and in the relation of the individual and of business to government. Lest there by any misunderstanding, I want to emphasize that the Institute's job will go on irrespective of these trends; that the Institute recognizes its responsibility to its members and to society at large to continue to advance the development and application of the electric sciences and arts and thereby to enhance the comfort and enrichment of mankind and the professional status of its members. We have an enviable record of achievement. We are rich in the tradition of service. Our future depends upon the increase in the knowledge of the electrical sciences and arts and the extent of their application to the service of man, and to me seems clearly to be independent of the forms of social and business organization which administer their application.

"The Engineer of the Future"

"THE ENGINEER of the future is going to make tremendous strides in this matter of studying human beings and. . .when he does so he will become the industrial manager of the world. This subject of management is in reality a branch of engineering, at least in this country. . . where in the last 40 years engineering has been always developing work which has been managed exclusively by engineers. Management is one of the great opportunities lying before the young engineering man; and some of the fields of management are so highly developed that we can give courses and write textbooks about them. . . .

"Of course there are a lot of other problems in this field. . .for instance, the very important problems of industrial relations between employer and employee. There is no group of men in industry today that is closer to and understands better the problems of both the employee and the employer than do the engineers. They can look upon the problems of both groups objectively.

"One of the great problems of industry today is the selection of men for executive positions. The right man must be bred, trained, and finally recognized in the group. The average life of an executive is between five and seven years. Sometimes he quits, sometimes he has a nervous breakdown, often he dies. One of the great problems in management is what can be done to keep this man on the job eight years instead of six. That entire field is one that people are tackling from an engineering point of view. The engineer, trained in habits of thought, is seeking the solution of these problems. The engineer should turn out to be a useful contributor in the world of economics as he has long since proven himself to be the best production manager in the world."

From an address of the same title delivered by President Harvey N. Davis of the American Society of Mechanical Engineers, at the spring meeting of the society, Los Angeles, Calif., March 25, 1938.

The Economic Status of the Engineer

By ROYAL W. SORENSEN
FELLOW AIEE

Data gathered by the Bureau of Labor Statistics are used by the author in this article to support his statement that "the economic status of the engineer is largely a matter determined by each individual engineer according to his particular personal qualifications and the relations these bear to the work he does and to the personalities of those persons with whom and by whom he is employed."

THE ECONOMIC status of the engineer is bifunctional in its scope—one part deals with the value of the integrated work which all engineers have contributed to the progress and welfare of mankind; the other part has to do with economic recognition in the way of social position and salary which engineers and their families receive in return for service rendered.

The study on which this article is based shows conclusions which may be briefed as follows:

Engineers, though suffering considerable loss of income and employment during the recent years of business depression, on the whole have fared much better than most classification groups, be they government, capital, profession, or labor.

Preceding the depression, there was no lack of employment for engineers and their compensation for the most part was equitable in comparison with the pay for other types of service.

The verdict of users of engineering service regarding the reasons why engineers who have not made satisfactory progress professionally or in their economic status is almost unanimous that such failures are due to deficiencies in personality, general culture, tact, industry, and so forth, rather than the result of lack of technical training.

Graduation from college is prerequisite to success in engineering, but per se does not guarantee an engineer.

The education obtained by taking engineering courses and engaging in the practice of engineering for most of those who have chosen the routes thereof has led to "the more abundant life" and a better economic status than the lots of the families from which engineers have come.

In the September 1932 issue, ELECTRICAL ENGINEERING announced for the first time the appointment of a committee to be known as the "Committee on the Economic Status of the Engineer." The function of the committee is set forth in Institute by-laws, article III, section 83, which says this committee "shall consist of five members, and shall consider matters relating to the position, function, and responsibility of the engineer in the development of human welfare, and make reports and recommendations to the board of directors thereupon. The committee shall co-operate with similar committees of other engineering societies, and shall also consider and report upon all matters referred to it by the board of directors, the president, and the national secretary." The language of this article shows wisdom in its formulation and clearly charges the committee with the duty of keeping informed and advising the members of the Institute, through its board of directors, of ways and means whereby they may be of service to mankind. Such responsibility would be overwhelming, were it not for the fact that all engineering aims at exactly the goal specified.

The world's economic evolution has resulted in much classification of the workers responsible for changing the habits of its citizens from those of the jungle to our present complex but regal standard of living, though jumbled be its attendant economic program under which we are muddling along.

One group of these workers is known as the professional men's group. Professional men are, perhaps, best defined by saying they are men who have professional education; that is, "the training that fits men for special vocations in which science is applied to the practical purposes of life. It supposes, as its basis, the knowledge and discipline which general culture affords."

Defining the Engineer

Many attempts have been made to write an all-inclusive definition for the engineer, but the rapid march of time has made each effort obsolete, even as the progressive science of engineering rather than the wearing out of machines has relegated many engineering products to the oblivion of the obsolete.

Engineers qualify as professional men by having professional education. Government research as to the "Educational Qualifications in the Engineering Profession" shows:[1]

"A first degree in engineering is now almost a prerequisite in order to obtain professional status and a position. Postgraduate work, however, is important only in a few of the professional classes. The tendency of engineers to transfer from the course of college specialization to other classes of work is negligible. These are a few of the facts developed in the survey of the engineering profession, which was undertaken by the Bureau of Labor Statistics in May 1935, at the request of the American Engineering Council."

Figures on which the above statements are based show that only 1.52 per cent of the engineers who began practice between 1930 and 1934 were not graduates. For all years up to 1929, 27.6 per cent of all engineers were not gradu-

Essential substance of a paper presented at the AIEE summer convention, Washington, D. C., June 20–24, 1938.

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1. For all numbered references, see list at end of paper.

ates. For all years up to 1935, 17.7 per cent of all engineers were not graduates. For all years up to 1935, 13.3 per cent of all electrical engineers were not graduates. Also the number of engineering graduates with more than one degree is very small, namely, one-half per cent and one-tenth per cent only having, respectively, masters and doctorate degrees.

The doubt expressed as to the importance of postgraduate work is challenged, because graduate work in engineering colleges is too new to provide enough statistical data to draw conclusions as to its value. There is strong evidence, however, that men who are qualified for and have completed graduate courses which are provided in properly manned and well equipped colleges for the study of modern science and mathematics as applied to engineering, have, for the most part, advanced in professional status at rates which show justification for graduate work. In the author's opinion, the limited number of men who have the special scientific and mathematical ability to warrant the continuation of postgraduate work unto the earning of a doctorate degree (and no others) should be encouraged toward that end.

A poet scanning these data and writing in Biblical language might well say, "It is easier for a camel to go through the eye of a needle than for a man to become an engineer without the advantage of graduation from an engineering college," or expressed in current language of the street, it may be said, "The odds are better than 98 to 1 you cannot be an engineer without graduation."

In fact the engineer finds that graduation does not end study, but that he must supplement his practice by continued study else he will lag behind just in proportion as his interest in research and study wanes. Perhaps, therefore, it will be easier to determine who are engineers by the manner in which they do their work rather than to judge by graduation, license to practice, or by passing examinations, often irrelevant to the kind of engineering done.

The law says a boy becomes a man the day he is 21 years old, but, except for legal privileges and voting, no change takes place on the 21st birthday, but rather a boy becomes a man when he puts away childish things and meets his problems in a manly way.

So it is with becoming an engineer. A man does not become an engineer because he graduates, or because he completes a test course and becomes a good draughtsman, mechanic, calculator, designer, or professor of electrical engineering. He becomes an engineer when he diligently and intelligently uses his God-given and hereditary talents, his education, his environment, his background, and his personality to produce new ideas and, through the medium of the crafts mentioned, finds ways and means for putting these ideas to work and makes a scientific analysis of his procedure in order that he may proceed by the engineering method rather than by cut-and-try or empirical methods.

Engineers, perforce, must at once be very co-operative and very individualistic. The co-operative characteristic is necessary because engineering problems of today are too large for one man to solve, and must be worked out by groups of men working in such close relationship as often to make practically impossible any acknowledgment as to the source of key ideas which unlock the problem solutions. Engineers must be individualists in order that each may contribute his share to the profession, by discovering in the daily tasks performed, new problems and their solutions. As illustrative of the latter point, consider the 27 Edison Medalists, beginning with Elihu Thompson and including the most recent one, Gano Dunn. No two of the entire 27 have traveled even similar paths to success. In fact, in all engineering history there are probably no case records which show that two engineers have done identical work, even in instances where promotions and other causes have made vacancies in organizations that result in succession appointments.

Thus we see that engineers in their relations with their work and fellow men have true professional status in that the particular contributions of each engineer to society are unique.

Economic Recognition

The other phase of the economic status of engineers, bluntly stated, is to what extent does all this work enable them to provide themselves and their families with good social positions and the use of the facilities for human betterment which engineers have made available. This part of the question, while not specifically mentioned in the Institute by-laws, is implied by the name of the committee, and committee consideration thereof is expected by the Institute members.

Statistical data regarding employment and income are now available in bulletins published by the United States Department of Labor, Bureau of Labor Statistics. Parts of the data in these bulletins have been published in ELECTRICAL ENGINEERING.

Table I. Comparison of Five Levels of Annual Earnings for All Professional Engineers Reporting in 1929, 1932, and 1934

Figures derived from adjusted data as explained on page 4 of bulletin, and without regard to employment status reported or type of education

Per Cent at Specified Income Level	Annual Earnings of More Than Specified Amount		
	1929	1932	1934
10	$7,466	$5,605	$5,138
25	5,012	3,827	3,429
50	3,412	2,574	2,286
75	2,509	1,698	1,473
90	1,878	889	872

A study of these data and much other information obtained from the printed page, by discussion with others, and by experience on the part of the author, seems to warrant the conclusion that the economic status of engineers in comparison to that of other citizens is for the most part reasonably equitable, though many engineers are of the opinion that the members of the engineering

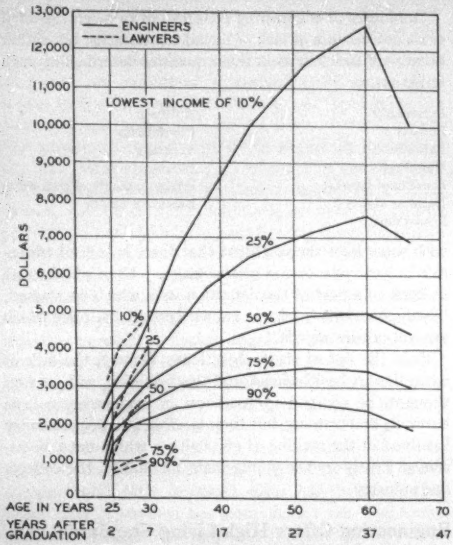

Figure 1. Earned annual income of engineers and lawyers according to age

Curves for engineers represent the findings for all the engineers of the United States; curves for lawyers represent the findings for California lawyers admitted to the bar in 1931

profession have received less reward than their work warrants.

Bulletin No. *R.* 497[2] opens with the sentence: "As far as is known, the recent depression was unique in its disastrous repercussions upon professional groups." This, after all, is just another way of saying the depression was terribly severe, extending even into the professional groups to such an extent as to show a simultaneous unemployment of about 11 per cent of all engineers, all of the several engineering classifications suffering to about the same degree, as might be expected, there was a greater percentage of unemployment for engineers over 53 or under 27 years of age. Summary analysis number 9 of this bulletin says:

"9. The type of education the professional engineer had received did effect variations in both the incidence and severity of unemployment. These factors were very much less for postgraduates than for engineers with other types of education. But as between engineers with first degrees in engineering and those whose college course was incomplete or who had attended noncollegiate technical schools, the differentials were very slight."

Other information shows less than three per cent of the graduates of some engineering colleges unemployed at any one time during the depression years 1930–35. No comparable data being available for the other professions, it is difficult to know just what a reasonable standard of depression unemployment should be, but there is every reason to believe that lawyers, physicians, and dentists, though busy, did not fare any better than engineers in regard to net income received for service rendered. It is also very certain that engineers, in that respect, fared better than skilled mechanics and other craftsmen who constitute much of our working citizenry.

Bulletin No. *R.* 543[3] shows among other things that during the five-year period of rampant unemployment, the number of engineers graduating into the profession was 25.3 per cent the number engaged in engineering in 1929. Since the nation-wide unemployment of engineers at any one time reached a maximum of 17.7 per cent, there was, even during unemployment times, a considerable amount of employment for the beginner in engineering. The number of engineering graduates, therefore, probably was not too high for normal times and the indication is that all should be needed by industry, if only persons well qualified for engineering work choose to enter the profession.

Bulletin No. *R.* 588[4] presents much very interesting data. The accompanying table I is part of table III of this bulletin. The table shows that in 1929 all but ten per cent of the engineers received wages equal to or better than the wages of skilled mechanics, as published in Bulletin No. 616, "Wages and Hours of Labor," which lists the pay for skilled and unskilled labor in many industries and shows mechanics' wages are $25 to $35 per week with occasional skilled occupations paying larger amounts.

Opportunity Outweighs Pay

First-degree engineering graduates start work at about $25 or $30 per week. Graduates with master's and doctorate degrees start at from $30 to $50 per week, the latter amount being reserved for men of special ability. These rates of pay appear just—the mechanic or skilled laborer being paid a premium over the common labor wage in recognition of his skill and the cost of its acquirement. The wage premium for neophite engineers is a recognition of the fact that time and money have been required for college training which will enable them to become engineers, rapidly, rather than as recognition of acquired proficiency as in the case of mechanics. The pay received by men just out of college, provided it keeps them from want, is relatively unimportant, as compared to opportunity for advancement in responsibility and salary. Salary advances for engineers of the United States and for lawyers of California, so far as the latter information is available, are compared in figure 1. The curves applying to engineers are taken from figure 1 of reference 4. The data pertaining to the lawyers of California is from an unpublished "Digest of a Survey of the Economic and Professional Status of California Lawyers During the First Five Years of Practice," prepared in 1937 by the committee for cooperation between the law schools and the state bar.

The curves for the engineers show favorable advancement in salary with age and experience for the upper half of those in the profession, as also does the rather limited data for the lawyers. It is interesting to note the long rise in earning capacity extending unto a man's 60th year of age and 37th year of practice. Observation, without confirming data, creates the opinion that lawyers and physicians follow the same laws in this respect. No actual

data have been made available for physicians, but an oral check with a number of them brought forth statements, all in agreement, to the effect that in the opinions of those interviewed, the curves for the engineers were, on the whole, indicative of the net salaries for physicians—the average for the physicians being perhaps a little better than the average for engineers; but less than ten per cent of the physicians have net incomes above the ten per cent curve for engineers.

All this information seems to indicate equity in the income of engineers as compared to skilled laborers, lawyers, and physicians.

The professional men are indeed fortunate in having occupations which provide for increasing service to fellow men as years add to skill and experience, and also in having at the same time increasing incomes which grow apace with the family expenses and often continue to grow beyond the period required to get the children established in their own homes and occupations.

Those of our profession who disagree with these findings, particularly as they apply to engineers, have two arguments against them—one the apparent greater expenditure of money by lawyers and physicians as compared to that of the engineers, which they have witnessed. It must be borne in mind that some of the expenditure made by physicians and lawyers is for office equipment and automobiles that must be used in connection with the practice of these professions. Also it is worthy of note that the expenditures which attract attention are usually those made by the more prosperous, rather than by the representative members of the profession.

Moreover, comparisons which men make purely by observation, rather than on the basis of exact data, between the spheres of their own activity and those of others, generally result in optimistic interpretations regarding the outside spheres, with a simultaneous pessimistic appraisal of their own. "The grass on the other side of the fence is always greener."

The second objection has to do with the exactness of the data obtained from returned questionnaires as compared to that which would have been available, had every engineer in the land returned a complete questionnaire. A complete report, would, of course, be impossible except by absolute governmental decree ordering a census of all engineers, but the data available which came from the 52,589 engineers who properly filled out and returned the questionnaire should give a fair cross section of the 167,268 engineers who received them.

Assuming the data used to be representative, the analysis has narrowed to two questions: (1) Why is there such great spread in income for men in the same profession who have gone through the same training courses, been subject to the same tests as to ability, and have survived the same processes of selection? (2) What are we going to do about it?

Many educators and others have often asked these questions and made surveys of industry, hoping thereby to find the answer, but all have ended with only a variety of general but authoritative statements by those who employ engineers. Some of these statements are:

Graduates of engineering colleges fail to reach expected goals not because of lack of technical education but rather because of deficiencies in those qualities described by such terms as:

Personality	Aptitude
Loyalty	Promptness
Patience	Accuracy
Humility	Judgment
Breadth of interest	Proper estimate of own value
Business ability	Executive ability
Leadership	

with sometimes the comment that there is lack of education in basic science and mathematics. All of which takes us back to a part of the definition with which we started, "it supposes as its basis the knowledge and discipline which general culture affords."

Only the last of these objections; namely, the lack of education in basic science and mathematics, will, at first thought, be charged to weakness in engineering college curricula and training, but there is a four fold responsibility involved in the making of an engineer which must be assumed jointly by the young man, his family, the college, and industry.

Engineering Offers High Living Standards

America, the land of opportunity, provides many avenues for rendering service and at the same time improving standards of living. Not the least of these are the engineering professions. Via engineering and the education provided by the engineering colleges, many men have reached social positions and attained economic rewards far better than those of the families from which they came. In fact, there are so few exceptions to this order of things, even among the poorer paid engineers, as to make perfectly valid some such declaration as: "Engineering is a profession through which the sons of small merchants, farmers, and laborers, as well as those of professional men and the prosperous in industry find golden opportunities to high living standards."

A large portion of the enrolled students in engineering colleges in part or entirely "work their way through." The author has, for more than a quarter of a century, cooperated with these men to make work, college courses, family budgets, and loan funds blend to the best advantage of all concerned. This blending process is not always easy, nor, though a certain amount of labor experience is desirable, is it advantageous for a student to be compelled to allot a very large part of his college time to earning money. In one college where the tuition is $300 per year and there are relatively few scholarships, one-sixth of the undergraduate student body and one-tenth of the graduate students are using National Youth Administration assistance. Nearly all the families to which these young men belong have incomes of $1,200 per year or less. According to the catalogue of the college in question, the minimum estimated cost per student for board and room, books, tuition, and so forth, but with no allowance for entertainment and clothing, is:

Students taking 21 meals in student houses per week . . . $840 per year

Students taking 15 meals (going home weekends)	740 per year
Nonresident students	390 per year

The cost per student in many free-tuition colleges, when all factors are considered is practically the same. If a family with an income of $1,200 per year (and there are those with less) must, with the aid of the student, apportion an amount equal to two-thirds the family income for the bare essentials of being in college, it is obvious there is little money available for travel, hotel life, theater, dances, and other social functions, or even for church activities, all of which have great bearing upon the phases of life which employers have declared are deficient in engineers to an extent which impairs engineering careers.

These deficiencies fortunately can all be remedied by any normal young man with capacity to complete an engineering course, if he is made aware of them, and will make an honest effort to know himself and apply the needed corrections. Keeping well is always simpler and better than curing illness, but continuing in illness is infinitely worse and sometimes inexcusable.

Being born and nurtured in an atmosphere of culture where all the graces of life are daily habits which can be acquired with little conscious effort has its advantages. When this experience has been denied the engineering students, colleges should provide clinics for correcting the deficiencies. Some of the more progressive engineering colleges have made progress in the right direction by having in their curricula a goodly proportion of cultural courses with the consequent necessity for postponement of the more special technical courses to graduate years. Industry also should not limit all its training courses for young engineers to the technique of the business, but should provide opportunity for them to learn of and correct faults which impair the rendering of the highest possible type of engineering service. College and industry together must show interest in our educational program from kindergarten on and co-operate with our engineering societies and the Engineers Council for Professional Development in extending their program for educating the public as to the requirements for being an engineer.

Industry should see to it that all who qualify as engineers be paid all the work done will warrant, and should not designate as engineering, work which is not engineering, but is only high-class clerical calculating, draughting, or skilled machine operation.

Engineers should make themselves thoroughly conversant and be sympathetic with all the problems of labor, skilled and unskilled, preferably through having had actual experience as workers in both classifications. They should not make entangling commitments to either capital or labor which may interfere with their great opportunities to correlate these two great industrial factors into teams that, working together at the business of applying engineering methods, cannot be defeated.

Fortunate indeed are the youths who find their talents and choices leading them into engineering; they can have a lot of fun following one of the many paths leading to enjoyable service for their fellow men, and at the same time providing so well a means of livelihood for themselves and their families.

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Voltage Distribution in the Welding Arc

A PAPER by H. von Conrady entitled "Investigation of the Voltage Distribution in the Welding Arc," which was published in *Elektroschweissung* (volume 8, June 1937, pages 101–06; July 1937, pages 125–28) recently has been translated by Herman J. Munz and is being distributed by the welding research committee of The Engineering Foundation. The author (1) describes apparatus devised as a part of a research subject under investigation at the experimental station for welding technique of the Technical University of Berlin, Germany, for measuring the voltage drop in welding arcs carrying currents as large as 1,000 amperes; and (2) presents results of tests made with that apparatus.

Electrodes made of iron, copper, and aluminum, all having diameters of 40 millimeters, were employed in the investigation. Test results showed that the arc characteristic for currents used in welding has a slowly increasing slope; in other words, the voltage increases with increasing current, assuming the length of the arc to be constant. Both the cathode voltage drop and the anode voltage drop are said to vary with the arc current.

The author found also that the voltage drop on the cathode is always larger than that on the anode, as should be expected in considering the energy regained on the anode. The magnitudes of the voltage drops, however, depend on the material used. For iron the voltage drop on the cathode is somewhat larger than that on the anode. The external shape of the unobstructed arc between iron electrodes was observed to be different from the shape of arcs between carbon, copper, or aluminum electrodes. Arcs between these latter materials graduate from a narrow limited point at the cathode in a cone-like shape to a wide base at the anode; however, the shape of the arc between iron electrodes is exactly reversed.

A few mimeographed copies of this translation are available from the Welding Research Committee, Engineering Foundation, 29 West 39th Street, New York, N. Y.

High-Voltage Gaseous and Fluorescent Tubes

High efficiency and wide variety of new colors may change the whole complexion of high-voltage applications

ALTHOUGH gaseous-discharge tubing (which usually is called simply "gaseous" tubing) had been used previously in the United States, the introduction of high-voltage neon and mercury tubes in 1924 inaugurated a new industry of such tremendous proportions that the whole aspect of outdoor electrical advertising was changed. The reasons for the wide acceptance of gaseous tubing were both functional and economic. By its use, advertising features could be outlined directly, thus offering better definition than by general flood-lighting of those features. In addition, the life of the tubing was relatively longer, the installation requirements were simple, and attractively colored light could be produced more efficiently than from incandescent sources. Rapidly the gaseous tube assumed its role as a major feature of the nation's "white ways."

Filter Glasses and Basic Colors

The light emitted as a result of an electrical discharge in a gas gives a line spectrum, and by the use of filter glass some of the lines may be absorbed and others transmitted. Neon gives a series of lines, including yellow and red, the net physiological effect of which is the characteristic orange red. If the proper red tubing is employed, all but the deep red light is absorbed and a ruby tube is the result. Similarly, activated mercury vapor gives blue and green lines, which result in a whitish blue light. However, by using "novial" glass, which absorbs the blue lines, a green tube may be obtained. If the proper blue glass is employed, a so-called "midnight blue" tube will result. The use of helium in tubes was not found practical until 1933, when special electrodes to permit its use were introduced. Helium gives a yellowish white light and if a yellow filter tubing is employed, a gold effect can be obtained.

Elementary Use of Fluorescent Tubes

The first commercial fluorescent tubes employed uranium glass. By its use with a mercury discharge a green fluorescence was obtained; and this, combined with the filtering effect of the tubing, gave a blue green light at an efficiency somewhat higher than that obtained from "novial" glass. However, mercury tubes continued to play only a minor role, because neon tubes were relatively brighter, and attempts were made to improve the efficiency of mercury tubes. It was well known that at the gas pressures then used a large part of the energy emitted by the discharge was in the form of ultraviolet radiations that was not utilized.

In 1935 "Lumophor" tubing was introduced in the United States. In this tubing a fluorescent material was incorporated as an integral part of the glass walls of the tubing. A wide variety of colors was made available, including a yellow green, blue, gold, and a few shades of white. This development was important because it increased the efficiency of production of some colors and introduced others previously not available from any type of gaseous tubes. Green tubes, which were five times more efficient than nonfluorescent tubes, were produced. These new tubes found wide use in the sign industry, and the white tubes were used to some extent in interior decoration. Although "Lumophor" tubing represented an advance in the application of high-voltage gaseous tubes, it did not utilize all the ultraviolet light that was available. Too

Photo by Powers

White fluorescent high-voltage tubing was used to illuminate this glass dance floor. The attractive design of a marine compass was simulated by coating the underside of the glass slabs with colored translucent paint

for Advertising and Architectural Lighting

By J. A. McDERMOTT
ASSOCIATE AIEE

much of the ultraviolet energy was lost in reflection and absorption by the glass walls of the tubing.

Coated Fluorescent Tubes

One improvement was the introduction of a method of making fluorescent materials adhere to the interior walls of the tubing. With this construction the ultraviolet radiations impinged directly upon the material to be activated, and the reflection of the radiations by the interior surface of the tubing and their absorption by the glass had no effect upon the efficiency of the tube.

The efficiencies obtained by this method were revolutionary, and in the instance of green reached 60 lumens per watt. Moreover, many new colors were made available. Research promised the development of high-efficiency white shades, and a full range of pastels. However a great amount of ground work had to be done to reduce the laboratory samples to a practical basis. Fluorescent materials that best responded to the ultraviolet radiation emitted by low-pressure tubes were evolved next.

General practice in the sign industry had established the use of tubes having a life of from 3,000 to 10,000 hours and it was essential that during the major part of this period the luminescence be practically constant. Fluorescent tubes would have to possess similar characteristics, so that a section replaced because of breakage would not stand in too sharp a contrast to adjacent sections of a display.

Improvements in the technique of coating, evacuating, and processing the tubes, together with improvements in the phosphors, have resulted in high-voltage fluorescent tubes that meet all the rigid requirements. These tubes, known as "Zeon" tubes, have been introduced only recently to the American market.

Fluorescence has been obtained also where neon is used in the tubes without any mercury. A certain amount of ultraviolet radiation is emitted by low-pressure discharges in neon. A gold-colored tube is produced by using a material that gives a green fluorescence. The addition of the green light to the orange red of the neon gives a golden effect. By the use of other phosphors various neon fluorescent effects are obtainable.

Characteristics of "Zeon" Tubes

The efficiencies of high-voltage gaseous tubes are somewhat dependent upon the conditions of installation, lengths of tubes, diameters, operating currents, and for "Zeon" tubes, the point on the saturation curve at which the fluorescent coating is being activated. In general longer tubes have the highest efficiencies, because a large part of the power loss is incurred at the electrodes.

The following average efficiencies may be expected:

Blue—20–25 lumens per watt; mercury activated
Green—45–60 lumens per watt; mercury activated
Orchid—20–25 lumens per watt; mercury activated
Warm white—30–35 lumens per watt; mercury activated
Cold white—30–35 lumens per watt; mercury activated
Yellow—18–20 lumens per watt; mercury activated

Essential substance of a paper presented at the AIEE summer convention, Washington, D. C., June 20–24, 1938.

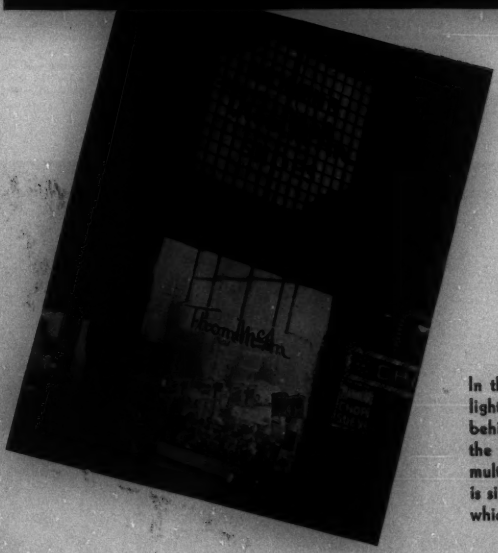
J. A. McDERMOTT is an engineer for Claude Neon Lights, Inc., New York, N. Y. He was graduated from Cooper Union Night School of Engineering in 1932 with the degree of bachelor of science in electrical engineering. Three years later he received the same degree from New York University. From 1928 until 1935 Mr. McDermott was employed as an engineer for Barr, Irons, and Lane, New York, and has been associated with Claude Neon Lights, Inc., for the last three years.

The author wishes to express his appreciation to Mr. Bassett Jones and the firm of Morgan, Hamel, and Engelken, illuminating engineers for the New York World's Fair 1939, for their co-operation in enabling the author to secure photographs of their designs.

The greatest display of high-voltage fluorescent tubes thus far was at the Paris Exposition of 1937. Many thousands of feet of tubing was used to obtain such colorful and spectacular displays as the lighting of the base of the Eiffel Tower

These "information" signs at the New York World's Fair 1939 are silhouetted against a background of translucent plastic material, which is illuminated from the back by blue fluorescent tubes

(Below) Serpentine tracery on pylons at the New York World's Fair 1939 produces a beautiful effect at night



(Middle left) "Aqualons" at the New York World's Fair will be illuminated by high-voltage blue tubing placed below the level of the water

(Center) Circles of blue and warm white tubing will provide general illumination around a booth, and a neon gold tube concealed in a reflector will give a golden glow to an "information" sign at the New York World's Fair

In this combination of architectural and advertising display lighting, lines of green fluorescent tubing were carried behind the joints of a glass-block wall. Vertical fluting on the interior surface of the blocks produces the effect of a multiplicity of tubes. Against the glass-block background is silhouetted a ruby-colored neon sign, the effectiveness of which is heightened by the complimentary value of the green background

Pink—15–20 lumens per watt; mercury activated
Gold—12–16 lumens per watt; neon activated
Salmon—12–16 lumens per watt; neon activated
Rose—12–16 lumens per watt; neon activated

A comparison between standard, nonfluorescent, gaseous tubes and the new fluorescent tubes reveal that the efficiencies have been increased by the following percentages:

Green—1,200 per cent
Gold—1,200 per cent
Blue—100 per cent

Comparisons of the other new colors with ordinary gaseous tube sources are useless because the new colors previously were not commercially obtainable in any form. A comparison of fluorescent tubes with incandescent sources for the production of colored light reveals the following increases in luminous efficiencies:

Green—4,000 per cent
Blue—3,000 per cent
Gold—100 per cent
White (warm)—250 per cent
White (cold)—350 per cent

The color of neon fluorescent tubes is dependent mostly upon the current, as the apparent color is a combination of the line spectrum of neon and the continuous but distributed spectrum of the fluorescent coating. The neon emission may be considered roughly as following a straight line at the lower values of current; however, the fluorescent material follows a saturation curve. For this reason, the color of any individual neon fluorescent tube changes from a hue associated with the fluorescent material to a reddish color as the current is increased. If the color is to be maintained, and higher tube currents are indicated as a means of increasing the light output, tubes having larger diameters must be used for neon fluorescence. In this way the balance between light from the neon spectrum and the light from fluorescent materials is maintained.

Winter Operation

Winter operation of high-voltage gaseous tubes always has presented some serious difficulties. Although neon tubes are not subject to any ill effects, cold weather causes a condensation in mercury tubes and a consequent dimming of the tubes.

For this reason, in the colder sections of the country the main features of signs always have been outlined in either helium or neon tubes. However, with mercury fluorescent tubes a multiplicity of colors will be available for practically all uses. Although cold weather causes a reduction of the light output, the intrinsic intensity is so high that the reduced light output is acceptable. Neon fluorescent tubes are not subject to any reduced efficiency in cold weather, and the new shades will broaden materially the choice of colors available.

General Practice

Fluorescent tubes will be actuated by high-voltage high-reactance transformers, and the methods of connection and installation will be similar in general to those previously used in sign work. Transformer voltages may range from 1,000 to 15,000. Currents of from 12 milliamperes up to 500 milliamperes are anticipated. General practice will fall into a range of between 12 and 60 milliamperes. Standard transformers operate at a power factor of about 0.50, but transformers with the power factor corrected to over 0.90 by means of capacitors are obtainable.

Dimming may be accomplished by means of voltage-control devices in the primary circuits of the transformers, or by adjustable chokes. It is not possible to get a complete variation from full intensity to darkness. At the lowest point from 15 to 25 per cent of the light remains. It has been found, however, that this is not an inconvenient arrangement. The most common requirement for dimming is in theatrical work. In such locations, multiple colors also are required, and by proper adjustment certain colors or groups of tubes are switched out successively, so that gradual light diminution is effected. The best results are obtained when the tubes themselves are concealed, and all other installations must be designed with special care.

The neon fluorescent tubes previously discussed would change color with change in intensity and hence they would not lend themselves readily to dimming.

Fluorescent tubing will be available in diameters of from eight millimeters up to 35 millimeters. Power con-

Another spectacular display of fluorescent-tube lighting at the Paris Exposition of 1937 was the Radio Building

Without following the usual trend to red neon, an unusual effect was derived here from the use of a triple row of blue fluorescent tubes in a recessed-letter sign. The 12-millimeter tubing requires a current of 60 milliamperes

sumption will range from $^1/_2$ to 25 watts per foot of tubing, depending upon the current, diameter of the tubing, and whether the tube is designed for use in colder climates. Where cold weather is anticipated the fluorescent tubes are specially treated to give them such characteristics that temperature changes will have the least effect.

Color Combinations

It is desirable in many instances to obtain white by a combination of gaseous tubes of different colors. In this way multiple effects may be obtained, and if dimming devices are included in the system, numerous attractive variations will be available. In addition, the more efficient green tubes may be used. These are the possible combinations of tubing that will result in sensations of white light:

Combination	Result
Red (neon) regular—Green	Slightly deficient in blue
Gold—Pink	Pinkish amber
Green—Gold	Deficient in blue
Pink—Green	Good
Gold—Blue	Good
Red (neon)—Green—Blue	Offers wide range of hues

Application of "Zeon" Tubing

High-voltage fluorescent tubes already have found numerous uses, both in the United States and in Europe, including decorative as well as advertising lighting. In many instances fluorescent gold tubing has been substituted for helium gold. Such displays have resulted in energy savings up to 80 per cent. However, it is believed that "Zeon" tubes in general will not affect loads materially, because of the tendency to use higher intensities not available previously. "Zeon" tubing has been used also for the illumination of marquees. For such a use at the Hampshire House in New York City a neon gold tube was substituted for amber bulbs and an energy saving of 50 per cent was effected.

The greatest display of high-voltage tubes, up to the present time, was at the Paris Exposition of 1937. Literally miles of tubing was used to produce such spectacular effects as the lighting of the Eiffel Tower base and the radio building. In addition, several indoor lighting displays were used to good advantage. Typical of these was the Ford showroom.

The Future Uses of High-Voltage Gaseous Tubes

As the "World of Tomorrow," the preview of the New York World's Fair 1939 gives the beholder some idea of the architectural uses to which this new medium may be adapted. Serpentine tracery on the pylons gives a beautiful night-time effect. Tubes of one-inch diameter were used for this application. One hundred milliamperes flow through two rose-colored tubes and a current of 50 milliamperes is used for the green tubes. Blue fluorescent tubes behind a plastic result in an attractively illuminated silhouette sign operating with remarkable economy.

Circles of blue and warm white tubing provide general illumination around a booth, and a neon gold tube concealed in a reflector gives a golden glow to the information sign. The circles are of 18-millimeter tubing and operate at 60 milliamperes. The gold neon tube operates at 60 milliamperes and is 24 millimeters in diameter.

An outstanding night effect was obtained by placing high-voltage blue tubing below the water level in the "aqualons." This color is set into contrast by the gold tubes in the vertical cylinders above. Bubbles rising through the water produce a shimmering effect. These units provide general street illumination in their immediate area, in addition to their purely decorative features.

The applications mentioned represent only a few of the designs that have been completed by the World's Fair engineers, and it is certain that the New York World's Fair will develop many new uses of high-voltage fluorescent tubes and will serve as a true indication of future trends.

Typical of the indoor applications of high-voltage tubes at the Paris Exposition was the Ford display room

The Role of the Engineering Library

What Should It Contain and How Should It Be Used?

By HARRISON W. CRAVER

LIBRARIES are universally recognized to be essential to modern civilization. In a world that gets most of its learning through the printed word, storehouses of print are a vital necessity. In this regard engineering differs in no way from the other learned professions. Whenever we wish to extend our knowledge beyond our immediate environment, we turn directly to a library. Obviously, libraries are necessary elements of our colleges and universities. Two practical questions that arise are: How shall the library be formed, and how shall it be used?

In discussing these questions, I shall lean heavily on my own experience. Although the Engineering Societies Library is not a college library, its work is much the same. Its users are students from institutions where local facilities are inadequate, and engineers in practice or engaged in research work. Because of its unusual book collection, it is called upon to supplement the resources of many colleges, both in the United States and abroad, by supplying literature and bibliographical assistance. Its broad function, then, is to assist the student of engineering.

Until recent times, the library needs of the engineers have received rather scant attention. The physical sciences and engineering have not been adequately represented in any but the largest of our general libraries. In most colleges and universities, even those with substantial libraries, the provision for engineering has been below the level of that provided for other departments. Often it has been inadequate for any but the simplest needs.

Various reasons (or excuses) for this condition are given. One is that engineers in the past have not been bookish people. In the days when our profession was more of an art and less of a science than it is today, when each problem was solved through the results of past experience rather than by applying scientific principles, our literature was less helpful. Unless a closely parallel problem had been discussed, the seeker found little but broad generalities, most of which he already knew.

Another difficulty in the past was that the published works on engineering were written chiefly for use as college texts. Now the textbook has certain definite boundaries, fixed by the level of knowledge the student brings to the subject and the time available for presenting it. Taking account of the capacity of the average student, every author finds himself limited in the amount of ground he may cover, and he can deviate from the accepted pattern only by his method of presenting the basic information.

The books of the past, therefore, being either confined to fairly elementary fundamentals or else almost entirely descriptive, have not offered much attention to earnest students. In the last few decades, though, there has been a new tendency, and a better one.

The engineer of today, to an extent never realized in the past, is aware that his activities rest upon a scientific foundation. Just as the industrial chemist always has thought that the processes he employed followed the theoretical laws of chemistry, the engineer is coming to perceive that scientific principles form the basis of all his methods.

The results are apparent in almost every branch of engineering. In metallurgy, in hydraulics, in machine design, and in communications, to name only a few examples, we see marked advances that have resulted chiefly from the study of pure science.

Out of this development are coming books of a new type. Not intended for classroom use, they can deal with more limited fields and do so more comprehensively. Basing their treatment upon exact science, they insure longer useful life for themselves. The quality and durability of our engineering libraries are improving rapidly.

A third obstacle to the development of engineering libraries has been the lack of librarians with experience in engineering. Too few librarians, unfortunately, have come from scientific and technological studies, and brought to their duties an understanding of these subjects. Confronted with the flood of publications available, they have found it difficult to choose wisely.

Under these circumstances they have had a tendency to evade the problem and turn their attention to more congenial fields, to those where their scholarship was surer and their judgment sounder.

Past conditions, therefore, have been far from ideal. A literature that was limited in scope and largely elementary, and with custodians lacking the proper qualifications, did not conduce to the growth of strong libraries. As a consequence, the development of engineering libraries has been almost entirely a twentieth-century phenomenon. Today there are a number of libraries devoted to applied science, as well as numerous departments in colleges, universities, and large public libraries that offer a wealth of such material, adequately catalogued and administered by competent librarians.

Essential substance of an address "The Role of the Library in Engineering Education and Research" delivered upon the occasion of the inauguration of President O. C. Carmichael of Vanderbilt University, Nashville, Tenn., February 4, 1938.

HARRISON W. CRAVER since 1917 has been director of the Engineering Societies Library, an institution supported jointly by the national societies of civil, mining and metallurgical, mechanical, and electrical engineers, and housed in the Engineering Societies Building, New York, N. Y. He received the degree of bachelor of science from Rose Polytechnic Institute in 1895 and of doctor of science in 1933. During the early years of his career he was chemist successively for the following concerns: Kirkpatrick and Company, Schoenberger Steel Company, Duquesne Reduction Company, and Virginia Iron, Coal, and Coke Company. His library career began when he became technology librarian for the Carnegie Library of Pittsburgh in 1900. In 1902 he was assistant superintendent of the Allegheny Iron and Steel Company, but returned to the Carnegie Library of Pittsburgh in 1903 and became librarian in 1908, which position he held until his present appointment. He is a member of various technical and library societies, and is currently president of the American Library Association.

Their growth has paralleled that of our research institutions and has greatly facilitated research work. Thanks to them, it has become possible for the research worker to obtain access, in one way or another, to any published material on any subject, usually with little delay and at moderate expense. Bibliographic paraphernalia has been developed which is constantly making the literature more accessible, by providing information as to what is in print and where it can be found. New methods are being devised for copying and distributing what is needed. The change in conditions during the past 20 years can scarcely be described.

What Should a Library Contain?

Every library that I know (and every college, for that matter) suffers from lack of sufficient income to achieve its ideals. Engineering has been defined by Sir Frederick Bramwell as "the art of drawing sufficient conclusions from insufficient premises." Librarianship might be paraphrased as the art of collecting a sufficient library with insufficient funds. No library can afford to purchase everything. Probably no one would ever wish to do so. No library has ever achieved the ideal of cataloging and indexing. Neither has any library known to me been able to meet the multifarious needs and wishes of readers as fully as was desired.

The material of the library falls roughly into three categories: periodicals, books, and bibliographic equipment. Of these, the first is the most essential.

If the eighteenth century was the age of the pamphlet, and the nineteenth that of the book, the twentieth is the period of the periodical. Never before has there been such a quantity and variety of magazines and journals rushing from our presses.

In such fields of active development as science and technology they have pushed the book into the background. The strength of a research library can be measured today by the size of its periodical department. It is in the periodical that one looks to find the details of new discoveries and inventions, fresh from the discoverer's mind and in his own words. Here, too, are found those hints of new fields, suggestions of unexplored paths, that are the inspiration for further investigations.

Over the book, the periodical has certain definite advantages. It can discuss subjects that are either too detailed or too limited to justify a book. It can be more timely and less formal, and can discuss a subject as it develops day by day. In the future, even more than in the past, the periodical will be first to report new discoveries, and will form the source from which material for books and inspiration for further study are drawn.

The number of periodicals, however, is amazing and far beyond the purchasing power of any libraries but the largest. Probably more than 3,000 periodicals of some professional interest to engineers are now being published. In addition, there are hundreds that have ceased publication but are still of value, and new ones are appearing almost daily.

Fortunately, the usual requirements can be met by a relatively small number. Fifty periodicals probably will cover all general needs. Another fifty will be adequate for ordinary research work. Beyond this, material can be obtained as needed from other centers.

The selection of the most important periodicals is difficult. The needs and preferences of the selector are apt to influence choice unduly, and some more impersonal method is desirable. One such method, devised by P. L. K. and E. M. Gross, was described in *Science*, in 1927 (October 28 issue, pages 385–9) and illustrated by application to chemical periodicals. A few similar studies have been published, and more would be welcome. In their absence, selection must be based on the experience of other libraries with similar needs.

Complete sets of periodicals, while desirable, are by no means necessary. Most demands will be for the issues of only the last 25 or 30 years. Much money can be wasted in attempting to obtain the early volumes of older periodicals, without regard to the demand for them.

In spite of common opinion, books, as distinguished from periodicals, are of secondary importance in the engineering library. One reason for this, already mentioned, is the fact that our books are so largely written for use as undergraduate textbooks. Useful as these are for instruction and quick reference to fundamentals, it does not seem necessary to have many works that cover the same field with about the same comprehensiveness, and differ only in method of presentation. Two or three on a subject are usually adequate.

Another reason that lessens the importance of these books is that they always lag behind current knowledge and hence rapidly become too out of date to be very useful. Obsolescence occurs at a high rate, five years of useful life being perhaps a fair estimate. After that, most current books are either revised or supplanted by better ones.

The book collection in use at any time is therefore relatively small. Most needs can be met with remarkably few titles, say 4,000 or 5,000. Except for some classical works, these should be books of very recent publication, so that the factual information may be the latest available.

An active engineering library therefore might comprise 5,000 books and, perhaps, 2,500 volumes of some 50 periodicals. As new books appear, others are withdrawn. If it is desired to keep them, they can be retained as a supplementary collection, and this is desirable if space permits, for they sometimes will be wanted by the research worker or historian. But in beginning, these uses may be neglected and attention focussed on immediate requirements only.

Supplementing the books and periodicals, every library should have adequate bibliographic equipment. This consists of indexes, abstract journals, and bibliographies.

No library can have too many of those aids to research. The smaller the library is, the more important they are, for they provide guides to what has been published, and what is not available locally can usually be obtained, if its existence is known. Abstract journals also often supply all that is needed for ordinary purposes. In many cases they make it unnecessary to have the original periodicals and

so are an economy, in spite of their relatively high cost. Such publications as *Engineering Abstracts*, *Science Abstracts*, *Chemical Abstracts*, and *Metallurgical Abstracts* are fundamental necessities to every research library.

The number of abstracting services is large, and is increasing as our literature becomes more voluminous and complex. Considerable overlapping exists, but is not a cause for worry, as the abstracting and indexing vary with the different viewpoints of those for whom the services are intended. Although the ideal would be a single publication which abstracted and indexed everything from all points of view, that ideal never will be reached, or even approached, in our day.

These journals, together with such indexes as the *Engineering Index* and the *Industrial Arts Index*, and the national bibliographies of the leading countries, are the means through which any research problem is most easily approached.

How Is the Library Used Effectively?

Tedious as library research is, it indubitably is the proper first step in any investigation. No better means exists for ascertaining the extent to which any field has already been covered, the results obtained, and the points where further study is needed. Much time-consuming, expensive experimental work can be avoided through the library. Every experienced librarian can cite specific instances of work which was done twice, often at large expense, because through insufficient reading the first investigation was unknown to the later student. Large sums have been invested in patents that were overthrown by searching the literature at relatively small cost.

Assuming that we have acquired our library, a modest collection of perhaps 10,000 books and volumes of periodicals and index journals, how shall we use it effectively? Here we approach an art that each must learn for himself. Methods will vary with individual tastes and with the fields of study. There is no universally applicable technique, nor can any one lay down rules that appeal to every worker.

A good method is first to ascertain whether any comprehensive treatises exist, by examining the most comprehensive bibliographies available. As a preliminary, this treatise will serve as a summary of work prior to the date of publication, or approximately so. Often use of it will obviate the need for examining earlier periodical literature or, if it does not do so, will provide convenient references to the relative articles.

Subsequent to the date thus established, the first search is for bibliographies that will be helpful. Usually none can be found, or those found are suspiciously brief and incomplete. Except for those lucky occasions when a satisfactory bibliography is to be had, one may as well turn at once to the abstract journals and engineering indexes, compile his own list of references that offer promise, and obtain these by consulting the originals.

Proceeding in this way, one is enabled to cover the subject as thoroughly as the occasion requires or as time permits. Eventually, it is possible, or should be, to disinter everything that has been published. This, however, is seldom done and the "complete" bibliography is exceedingly rare.

As thus outlined, the searcher's method seems very simple. Actually, of course, complications arise that call for all his skill and knowledge. Indexing and classifying are arts that are far from perfect, and it often is difficult to trace the desired subject through all the vagaries of various workers.

In different indexes various names are used for the same things. Terminology changes from time to time. Articles that fall into one group when classified by a physicist sometimes are classified quite differently by an electrical engineer. Practically never does one index or abstract journal cover its field completely. In addition, indexes seldom go beyond the main subject of an article, and nothing but direct examination will discover the hidden information within it. All these difficulties arise to hamper the searcher, but if he is sufficiently persevering and industrious, he eventually will find what exists on his subject.

A search of any magnitude is almost sure to bring to light material not in the local library, which must be consulted elsewhere. In the past, this often has been difficult, if not impossible, as many libraries are unable to lend their possessions. Fortunately, modern methods of copying have developed to a stage where material can be copied cheaply and accurately. The use of the Photostat has spread rapidly in recent years, until most libraries can supply photographic copies. Very recently attention has been directed toward microcopying upon film, a method of great promise for the research worker. The "microfilm" method is especially valuable for reproducing long documents, such as complete books, more cheaply than was possible in the past. Some form of projector is necessary to produce a readable image, and a variety of apparatus is already available.

Through the development of bibliographic equipment which enables librarians to ascertain where given documents exist, and of good methods for reproducing them, the entire book resources of the world are rapidly becoming accessible to every worker, regardless of his location. Current tendencies undoubtedly will affect the management of the college library. No longer will it need to be considered as an isolated institution that must rely wholly on itself; instead, it may be considered as one of a system of co-operating organizations, with resources pooled to a certain degree. Intelligent use of the facilities available for obtaining seldom-wanted material through means other than direct purchase should release funds that can be used more effectively for ordinary needs.

An engineering library may be regarded as a laboratory. Like other laboratories, it is a place for study and research. Like them, its assets are personnel, equipment, and housing. Also like them these assets are important in the above order. A good librarian will get better results with meager equipment than a poor one can get with all the books in print. The best collection of books possible is desirable, but best and largest are not synonymous terms. Good housing is always an advantage, but to sacrifice books and personnel for a handsome building is a frequent mis-

take. After all, the Curies did their brilliant work in a shed, and many libraries are giving excellent service in poor quarters.

Because the library is an essential tool in research work today, and promises to become even more important hereafter, college students would profit immensely from more instruction in its use. Too many leave college with no idea of the technique of searching, and hence find themselves helpless when cut off from professional advice. If, from time to time, problems were assigned for solution in the library, instead of the laboratory, this might be corrected to a degree.

No better description of the role that the library can play in research is to be had than the remarks on the scientific use of literature in Wiedlein and Hamor's "Glances at Industrial Research:"

"The scientific use of literature, or, as it is technically termed, bibliochresis, has the pilotage of all scientific investigation. It has, in fact, the same relation to research as the latter has to management; it is the intelligence service of all orderly inquiry, the preparational agent of factual determination, the guide of experimental trial in eliminating chance, in the whole realm of science, whereby the sedulous worker his laboratory course does steer."

These distinguished research workers speak warmly of the necessity of a literature search as the prelude to experimental investigation. It prevents waste through needless repetition; it is also, they say, a necessary "discipline for the self-conceit of the researchful mind."

Electric Locomotives—1888 and 1938

Fifty years' progress in electric locomotives was shown recently to the public by the New York, New Haven and Hartford Railroad. Marking delivery of the first of six new streamlined single-phase locomotives for express passenger service, shown in an accompanying illustration, a train of eight locomotives representing freight and passenger types built from 1888 to 1938 was exhibited at various points on the system.

The freight locomotive of 1888, shown here as it was exhibited on a flat car, was built for the Ansonia, Derby and Birmingham Electric Line, and is said to have been the first electric freight locomotive in the United States. It operated on 500 volts and was capable of hauling 35 tons at less than ten miles an hour.

The new 3,600-horsepower passenger locomotives are expected to haul 1,200-ton trains at 80 miles per hour. They are equipped to run from a single-phase 11,000-volt overhead trolley, or 600-volt d-c third rail. Electropneumatically operated changeover switches are provided for adapting the traction motor circuits to either a-c or d-c operation. With a-c operation the six twin motors are connected two in a series with three groups in parallel; 20 main transformer steps are provided. Two motor combinations are used for d-c operation, one with all six motors in series and the other with two in series and three groups in parallel. Rated continuous a-c tractive effort is 24,200 pounds; continuous d-c tractive effort is 26,900 pounds. Total weight, fully loaded, is 432,000 pounds; total length is 77 feet.

News

Of Institute and Related Activities

Pacific Coast Convention Affords Vacation Opportunities

As announced in previous issues, the 1938 Pacific Coast convention of the AIEE will be held in Portland, Ore., August 9–12. At this time the scenic beauty of Oregon is usually at its best, and these dates have been selected to afford members and their guests the opportunity to combine vacation trips with attendance at the convention. The program includes six technical sessions, two student sessions, a golf tournament on the beautiful scenic course of the Oswego Lake Country Club, interesting inspection trips, and a variety of entertainment. Convention headquarters will be in the Multnomah Hotel.

Vacation Hints

Opportunities exist to visit a number of points of scenic and recreational interest. Many of Oregon's mountain lakes and streams abound with fish and provide some of the best fishing to be found in the country. Scenic points or routes which may be visited either as side trips or as part of the trip to Portland include: Crater Lake (Ore.); Oregon Caves; Oregon Coast Highway; Columbia River Highway; Mt. Hood (Ore.); Wallowa Mountains; Mt. Ranier (Wash.); Olympic Peninsula (Wash.); Coulee Dam (Wash.); Victoria, B. C., and Vancouver Island, B. C. The trips committee will be glad to assist in planning trips. A request to Vernon B. Wilfley, trips committee chairman, 914 Porter Building, Portland, Oregon, will bring the desired information.

Technical Sessions

Six technical sessions, including one joint communication session with the Institute of Radio Engineers, will present a variety of timely technical subject matter. Power transmission, particularly as related to several large western engineering projects, will be brought forth in several papers. One of the six sessions will be a symposium on the operation of the Boulder Dam transmission line. Another session, which will deal with power transmission and related subjects, includes a paper describing the pumping system of the Colorado River Aqueduct and another paper in this session treats the subject of phase-angle control of system interconnections.

Student Activities

The dinner and joint conference on student activities will be held on the evening of Tuesday, the opening day of the convention. All student delegates and counselors, as well as others interested in student activities, should attend this important event.

The two student technical sessions will be held on Wednesday and Thursday afternoons. All students are invited and expected to attend all convention activities, including technical sessions, entertainment, and inspection trips, as far as they are able.

Schedule of Events

Tuesday, August 9

9:00 a.m.—Registration

10:00 a.m.—Opening of convention

10:15 a.m.—Address of welcome and response

10:30 a.m.—General session, including address by President-elect John C. Parker on "Engineering Orientation"

2:00 p.m.—Measurements and basic sciences session

Electrical machinery and protective devices session

6:00 p.m.—Reception

7:00 p.m.—Student-counselor dinner and conference (All interested in student activities welcome)

Wednesday, August 10

9:00 a.m.—Symposium on operation of Boulder Dam transmission line

2:00 p.m.—Student technical session

Golf at Oswego Lake Country Club, swimming and boating party, putting contest for ladies

7:00 p.m.—Buffet supper

9:00 p.m.—Orchestra, dancing, awarding of golf prizes, etc.

Thursday, August 11

9:00 a.m.—Communication—joint session with IRE

2:00 p.m.—Transmission and related subjects session

Student technical session

7:00 p.m.—Banquet at Multnomah Hotel, orchestra and entertainment

Friday, August 12

Choice of trips to Bonneville Dam, Ariel hydro plant, Oak Grove plant, Pacific Telephone Company plant, steam plants, 110-kv submarine cable crossing, underground systems, lumber and paper mills, etc.

A post-convention trip may be arranged to the new Timberline Lodge on Mt. Hood.

Joint Session With IRE

The Pacific Coast meeting of the Institute of Radio Engineers will be held in Portland, August 10–12, with headquarters in the Multnomah Hotel. The AIEE will hold one joint technical session with the IRE. Members of either organization will be welcome at all technical sessions of both Institutes.

Entertainment

Social activities of the convention will begin with a brief informal reception on Tuesday evening to permit meeting the officers and their families and renew acquaintances. On Wednesday evening a buffet supper will be held at the Oswego Lake Country Club. The golf prizes will be presented and there will be an informal dance in an ideal summer setting. On Thursday evening a banquet will be held in the grand ballroom of the Multnomah Hotel, which will be followed by entertainment.

Convention headquarters in the Multnomah Hotel will be open Monday afternoon and evening to serve as a bureau of information for visiting members and friends, and Monday evening the reception committee will hold "open house" on the mezzanine floor.

Women's Entertainment

In addition to the foregoing entertainment the following events have been specially arranged for the visiting women. On Tuesday afternoon, 2:30 p.m., a tea will be held in a private residence on the heights overlooking the city of Portland and the Willamette River. In the evening no general dinner meeting or entertainment has been arranged, with the thought that the reception may lead to congenial, private dinner parties and a pleasant evening. Wednesday morning will be spent in shopping or visiting places of interest in and around Portland and the women on the reception committee will be available to assist when needed. In the afternoon a putting contest will be held on the putting green of the Oswego Lake Country Club. All contestants will be required to wear golf shoes. Those not wishing to participate in this contest may go boating or swimming. Thursday, 1:30 p.m., a bridge luncheon will be held at the Portland Golf Club.

A reception committee of local women will be at the registration desk to greet old friends, make new friends, and be of general assistance. Arrangements will be made for the care of children of the convention visitors, so that parents may attend scheduled events or inspection trips. Those planning

to bring their families are asked to notify the committee in advance.

Sports

Wednesday afternoon has been set aside for the annual golf tournament, which will be held at the Oswego Lake Country Club. This course, in addition to being considered one of the most beautiful and scenic in the whole country, will provide an excellent opportunity for golfers to prove their ability.

The principal contest will be for the Fisken Cup, now in the possession of Dean R. H. Dearborn of Oregon State College. This will be medal play, with full handicap allowance, and will be limited to AIEE members. Several other events have been arranged which are also open to nonmember guests upon the payment of an entrance fee. All players, members and nonmembers, are eligible to receive prizes with the single exception of the Fisken Cup. Many prizes for special achievements, such as long drives and closest approach, will be awarded. It is planned to have match play against par with full handicap and a blind bogey event in which each player is permitted to establish his own handicap.

If help is desired in arranging a foursome, please advise the sports committee as soon as possible so that satisfactory arrangements may be made. Arrangements may be made to start earlier than 2:00 p.m. As an alternative to the golf tournament, those attending the convention may join boating parties, swim in Lake Oswego, or take trips around the lake in a power launch.

Inspection Trips

One of the features of the convention will be a specially arranged trip to the Bonneville Dam project. The 40-mile drive to Bonneville is along the Oregon bank of the Columbia River on the famous Columbia River Highway, which passes Multnomah Falls and other well-known beauty spots. Guides will be provided at the power plant and ample time allowed for inspection of the project and the adjacent fish hatchery.

Other out-of-town trips may be arranged to the Ariel hydroelectric development and to the Oak Grove hydroelectric development, where the Northwestern Electric Company and the Portland General Electric Company, respectively, will act as hosts. Also trips may be arranged to any one of a number of nearby lumber and paper mills.

Among the local trips arranged are those to the Pacific Telephone and Telegraph Company's plant, the Northwestern Electric Company's 110-kv Columbia River submarine cable crossing, various steam plants of the power companies, and sight seeing trips in and around Portland.

Those passing through or visiting in Corvallis will find members of the electrical engineering department "at home" in Apperson Hall on the Oregon State College campus on Monday, August 8, and Saturday, August 13.

Registration

Members who plan to be in Portland preceding the convention should indicate that fact when returning their advance-registration card, as the reception and trips committees would welcome the opportunity of

Tentative Technical Program

Photo-offset copies of authors' manuscripts, exclusive of addresses, may be obtained in advance of the convention by writing to the AIEE Order Department, 33 West 39th Street, New York, N. Y. Only numbered papers will be available in advance copy form. If ordered by mail, price 10¢ per copy; if purchased at Institute headquarters or at the convention, price 5¢ per copy. Coupon books in $1.00 and $5.00 denominations are available for those who wish to avoid remittance by check or otherwise. Most of the papers ultimately will be published in ELECTRICAL ENGINEERING or the TRANSACTIONS.

Tuesday, August 9

10:30 a.m.—General Session

Address: ENGINEERING ORIENTATION, **John C. Parker**, AIEE president-elect.

Address: THE ATOM SMASHER, **A. W. Copley**, Westinghouse Electric and Manufacturing Company.

99. SELECTION AND DESIGN OF THE ELECTRIFICATION OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE RAILWAY, **W. P. Monroe**, consulting engineer.

100. TRENDS IN THE DESIGN AND ARRANGEMENT OF ELECTRICAL EQUIPMENT IN HYDRAULIC POWER PLANTS, **C. C. Whelchel**, General Electric Company.

2:00 p.m.—Measurements and Basic Sciences

101. POLARITY LIMITS OF THE SPHERE GAP, **F. O. McMillan**, Oregon State College.

102. USE OF BISMUTH BRIDGE MAGNETIC FLUX METER FOR A-C FIELDS, **G. S. Smith**, University of Washington.

103. A VARIABLE REGISTER RATIO WATT-HOUR METER, **G. R. Shuck**, University of Washington.

104. SIMILITUDE OF CRITICAL CONDITIONS IN FERRORESONANT CIRCUITS, **W. T. Thomson**, Kansas State College of Agriculture and Applied Science.

2:00 p.m.—Electrical Machinery and Protective Devices

105. APPLICATION OF COPPER-OXIDE RECTIFIERS, **E. W. Morris**, Westinghouse Electric and Manufacturing Company.

106. SELF-EXCITATION OF INDUCTION MOTORS, **C. F. Wagner**, Westinghouse Electric and Manufacturing Company.

107. AN APPLICATION OF DECELERATION TEST METHODS TO THE DETERMINATION OF INDUCTION MOTOR PERFORMANCE, **R. W. Ager**, University of California.

108. STATIC POWER LIMITS OF SYNCHRONOUS MACHINES, **C. F. Dalziel**, University of California.

43. TESTING AND APPLICATION OF LIGHTNING ARRESTERS, Lightning arrester subcommittee.

Wednesday, August 10

9:00 a.m.—Symposium on Operation of Boulder Dam Transmission Line

109. GENERAL OPERATION OF TRANSMISSION LINE, **W. S. Peterson**, Bureau of Power and Light, City of Los Angeles.

110. CORONA EXPERIENCE ON TRANSMISSION LINE, **Bradley Cozzens** and **W. S. Peterson**, Department of Water and Power, City of Los Angeles.

111. INSULATION AND LIGHTNING PROTECTION, **Bradley Cozzens**, Department of Water and Power, City of Los Angeles.

112. CARRIER CURRENT EQUIPMENT, **J. D. Laughlin**, Bureau of Power and Light, City of Los Angeles.

113. TRANSMISSION LINE RELAY PROTECTION, **L. L. Draper**, Bureau of Power and Light, City of Los Angeles.

Thursday, August 11

9:00 a.m.—Communication—Joint Session With IRE

114. NARROW BAND TRANSMISSION SYSTEM FOR ANIMATED LINE IMAGES, **A. M. Skellett**, Bell Telephone Laboratories, Inc.

115. DEVICES FOR CONTROLLING AMPLITUDE CHARACTERISTICS OF TELEPHONE SIGNALS, **A. C. Norwine**, Bell Telephone Laboratories, Inc.

LOUD SPEAKER CONSIDERATIONS IN FEEDBACK AMPLIFIERS (IRE paper), **H. S. Knowles**, Jensen Manufacturing Company.

SOME DEVELOPMENTS AND PROBLEMS OF DEMOUNTABLE TUBE DESIGN (IRE paper), **C. V. Litton**, Engineering Laboratories.

PRACTICAL APPLICATION OF FACSIMILE BROADCASTING (IRE paper), **H. C. Singleton**, Radio Stations KGW and KEX.

2:00 p.m.—Transmission and Related Subjects

116. THE PUMPING SYSTEM OF THE COLORADO RIVER AQUEDUCT, **J. M. Gaylord**, The Metropolitan Water District of Southern California.

117. THE ELECTRICAL STRENGTH OF AIR AT HIGH PRESSURE, **H. H. Skilling**, Stanford University.

118. PHASE ANGLE CONTROL OF SYSTEM INTERCONNECTIONS, **R. E. Pierce**, Ebasco Services, Inc., and **B. W. Hamilton**, The Montana Power Company.

119. THE ELECTROSTATIC UNBALANCE OF TRANSMISSION LINES AND ITS EFFECT ON THE APPLICATION OF PETERSEN COILS, **J. A. M. Lyon**, Saginaw, Mich.

meeting with, and furnishing suggestions for trips to, all early arrivals.

Registration may be completed upon arrival at Multnomah Hotel, headquarters, Monday evening, August 8, and should be completed, if possible, before 10:00 a.m. Tuesday. A registration fee of $2.00 will be charged all nonmembers, except Enrolled Students and the immediate families of members.

Hotel Rates

The rates of the Multnomah Hotel, convention headquarters, as well as those of some of the other hotels are listed in an accompanying tabulation. Members should make their hotel reservations by writing directly to the hotel of their preference. The Multnomah offers a special rate for students (several per room) of $1.50 per person per day.

One of the greens on the scenic and sporty Oswego Lake Country Club's course, where the golf tournament will be held at the AIEE Pacific Coast convention. Lake Oswego and Mount Hood may be seen in the background

Committees

The personnel of the 1938 Pacific Coast convention committee is as follows: General committee—E. F. Pearson, *chairman;* D. F. Smith, *vice-chairman;* Corbett McLean, *secretary;* John Bankus, *treasurer;* C. Arnott, A. M. Bohnert, C. C. Boozier, R. O. Brosemer, H. V. Carpenter, A. W. Copley, L. G. Fear, W. F. Grimes, M. F. Hatch, N. B. Hinson, C. H. Hoge, J. P. Jollyman, O. L. LeFever, F. M. Lewis, C. E. Magnusson, W. S. McCrea, F. O. McMillan, H. L. Melvin, L. T. Merwin, G. W. Miller, A. S. Moody, H. S. Osborne, E. F. Peterson, A. C. Pratt, R. W. Preston, G. E. Quinan, C. E. Rogers, M. A. Sawyer, E. F. Scattergood, H. H. Schoolfield, H. H. Skilling, G. H. Smith, R. W. Sorensen, A. LeRoy Taylor, A. Vilstrup, and C. A. Wolfrom. Chairmen of subcommittees—O. B. Coldwell, *finance;* Walter Brenton, *program;* Sidney E. Caldwell, *registration;* R. J. Davidson, *hotel;* Vernon B. Wilfley, *trips;* Charles B. Carpenter, *publicity;* L. R. Elder, *reception;* A. H. Kreul, *entertainment;* J. C. Henkle, *golf;* Mrs. J. F. Spease, *women's entertainment;* A. L. Albert, *student activities;* and Gwynn E. Bishop, *transportation.*

Principal Hotels in Portland, Ore., and Rates

Hotel	City Blocks from Headquarters	Single Room With Bath	Double Room With Bath
Multnomah	0	$2.50 to 8.00	$3.50 to 10.00
Benson	4	3.00 to 7.00	4.50 to 10.00
Heathman	12	2.50 to 6.00	3.50 to 7.50
Portland	8	3.50 to 5.00	5.00 to 7.00

Future AIEE Meetings

Pacific Coast Convention
Portland, Ore., August 9–12, 1938

Southern District Meeting
Miami, Fla., November 28–30, 1938

Winter Convention
New York, N. Y., January 23–27, 1939

South West District Meeting
Houston, Texas, Spring, 1939

North Eastern District Meeting
Springfield, Mass., May, 1939

Summer and Pacific Coast Convention (combined)
San Francisco, Calif., June 26–30, 1939

Additions to Member-for-Life List

Membership for life is granted by the Institute for either of the following two reasons: a member has paid annual dues for 35 years; or has reached the age of 70 and has paid dues for 30 years.

Those who have become members for life during the preceding year are listed annually in Electrical Engineering. The list that follows indicates those members who have become members for life since the publication of the last preceding list in the June 1937 issue:

H. C. Abell
W. P. Abendroth
J. G. Barry
Paul L. Battey
W. H. Beattys, Jr.
Leon Beauchamp
C. A. Bessey
H. M. Beugler
W. L. Bird
S. H. Blake
C. E. Bonine
R. B. Bonney
J. E. Brown
W. H. Browne, Jr.
J. A. Brundige
C. I. Burkholder
W. G. Burns
Edmund G. Burr
L. M. Cargo
W. M. Carlebach
H. V. Carpenter
Markham Cheever
H. P. Clausen
F. W. Clements
F. H. Clough
C. B. Coates
S. K. Colby
G. P. Cole
C. W. Comstock
A. L. Cook
C. A. Cora
A. S. Crane
J. A. Cranston
J. R. Crocker
H. P. Daniels
J. H. Davis
W. F. Dawson
W. F. Dean
M. E. de Marchena
E. L. Doty
J. C. Dow
H. Dowie
C. G. Durfee
L. L. Elden
F. M. Farmer
E. M. Fitz
T. J. Fleming
J. T. Flickinger
F. F. Fowle
M. M. Fowler
A. A. Frank
B. V. French
L. B. Fuller
E. M. Gerry
C. F. Gilcrest
E. H. Ginn
J. G. Glassco
C. D. Gray
L. D. Gray
D. Hall
H. C. Hall
H. Y. Hall
M. R. Hanna
P. T. Hanscom
H. R. Harper
James Harrison
G. A. Harvey
L. A. Hawkins
J. E. Hayes
R. H. Henderson
H. H. Hess
A. C. Hobble
C. A. Hobein
E. Holcomb
E. B. Holden, Jr.
H. A. Holdredge
H. M. Hope
R. S. Hopkins
W. S. Hunt
A. Hussey
W. C. Jessup
F. B. Jewett
J. C. Johnson
G. H. Jones
W. S. Kelley
C. B. Keyes
J. B. Klumpp
G. S. Laing
A. S. Langsdorf
A. H. Lawton
J. E. Lear
C. Le Grand
G. Lobo
J. E. MacDonald
W. L. Mann
R. H. Manson
W. C. Marlow
L. G. Martin
W. S. Wyman
Ross B. Mateer
Howard Maxwell
M. C. McKay
N. C. McPherson
P. S. Millar
A. A. Miller
A. H. Moraweck
C. T. Mordock
C. H. Moritz
W. S. Murray
W. G. Nagel
R. J. Naucler
J. B. Noe
H. H. Norris
T. A. Panter
K. A. Pauly
H. C. Pease
R. B. W. Peck
H. A. Perkins
J. H. Perkins
C. L. Perry
G. W. Pickard
G. A. Pierce, Jr.
H. T. Plumb
A. C. Pratt
G. R. Radley
K. C. Randall
O. M. Rau
C. E. Roehl
A. F. Rolf
B. P. Rowe
S. W. Rushmore
M. C. Rypinski
P. C. Saccaggio
H. W. Scharf
M. Schreiber
F. F. Schuetz
A. K. Selden, Jr.
F. L. Sessions
Robert Sibley
Arthur Simon
E. H. Smythe
T. H. Soren
L. B. Spinney
S. D. Sprong
O. C. Spurling
H. B. Stabler
A. L. Stadermann
N. R. Stansel
Robert Steck
G. H. Stickney
J. F. Stockwell
Edgar Strasburger
J. B. Taylor
A. H. Timmerman
M. S. Towson
C. R. Underhill
L. E. Underwood
R. W. Van Norden
C. H. Van Slyck
J. F. Vaughan
W. N. Voorhees
J. A. Walls
H. M. Warren
H. S. Warren
S. B. Way
J. Lloyd Wayne, 3rd
G. E. Wells
F. S. Wilhoit
F. T. Wright

Lenox, Mass., Scene of District Meeting and Student Convention

A PROFITABLE and especially pleasant period was enjoyed by the 400-odd persons who attended the AIEE North Eastern District meeting at Lenox, Mass., May 18–20. Ideal is the only word adequately describing the housing, meeting, and other facilities provided by the local meeting committee, which arranged with the management of the Curtis Hotel to advance the date of seasonal opening to accommodate the meeting and, in effect, to turn over the entire facilities of the spacious building to those attending.

The three-day meeting entered promptly into its business with the first technical session immediately following registration Wednesday morning; the second technical session Wednesday afternoon. Thursday morning was devoted to a general session, and Thursday afternoon to inspection trips. Two student sessions were held Friday, the afternoon session in parallel with the concluding technical session. Major social events included a stag smoker for the men, and bridge tournament for the women Wednesday evening and a mixed banquet addressed by Past Vice-President W. H. Timbie Thursday evening. This sequence of activity worked out smoothly and apparently to everyone's satisfaction. Details are reported on this on the following pages. Attendance figures are given in an accompanying tabulation.

Analysis of Registration at Lenox Meeting

Classification	Location: Pittsfield Section	District 1*	Other Districts	Totals
Members	109	106	18	233
Students	9	106	19	134
Men guests	3	19	6	28
Women guests	4	13	5	22
Totals	125	244	48	417

*Outside of Pittsfield.

Doctor Darrow and Roger Babson Speak

The general session Thursday morning was opened by Chairman K. B. McEachron of the District meeting committee who turned the gavel over to Past-President C. C. Chesney as chairman of the session. Appropriate introductory remarks were made in turn by Chairman Aram Boyajian of the Pittsfield Section, General Electric Pittsfield Plant Manager L. E. Underwood, Vice-President A. C. Stevens, and National Secretary H. H. Henline speaking on behalf of President W. H. Harrison who then was on his way from a tour of official visits in the Middle West.

Doctor Karl K. Darrow, renowned physicist of the Bell Telephone Laboratories of New York City, lectured on the subject of "Radioactivity—Artificial and Natural." The full text of this address may be found beginning on page 193 of the current May issue of ELECTRICAL ENGINEERING.

Roger W. Babson, widely known statistician, and assistant secretary of labor in the cabinet of Woodrow Wilson during the World War chatted with his audience on the theme "If I Were President of the United States." As "one fundamental necessity in the correction of evils of the present era," Mr. Babson recommended that "wages be so equalized as to make life in cities so unpleasant for some people that they will go back to the farm." In speaking further of wages, he emphasized that "wages cannot exceed the aggregate value of the products of labor, and should be distributed to individuals only in accordance with the proportion of individual contribution in products, efficiency, etc., and not in accord with artificial bases set up by law.... Prices and wage levels are inseparably related by economic laws, and to legislate higher prices or wages can only upset and aggravate the situation. . . the standard of living can be raised only through boosting total production; never by curtailing it—neither can it be raised by subsidizing an inefficient industry at the expense of those that are better managed."

Mr. Babson urged the necessity for "catching up spiritually with our advanced stage of material development," giving emphasis to this by the following comparisons: "Our political power has been increased 100 per cent—by the women's vote; our power to travel has been increased 500 per cent—by air, water, road, and rail; our power to see has been magnified 1,000 per cent—by the motion picture; our power to hear has been increased by 10,000 per cent—by the radio; but how much has our judgment, self-control, self-dependence, and recognition of our public responsibility increased?" He expressed the belief that "the churches of all denominations are the basic hope of America today."

Distribution Voltage Regulation

Reflecting experiences of operating companies and touching upon various phases of the problem of voltage regulation on distribution circuits, with special emphasis on the problems incident to the extension and development of rural electric service, were the following four papers which are scheduled for publication in the TRANSACTIONS section of ELECTRICAL ENGINEERING for September:

SYSTEM PLANNING AND OPERATION FOR VOLTAGE CONTROL, T. J. Brosnan, Buffalo, Niagara and Eastern Power Corporation.

VOLTAGE-REGULATING-EQUIPMENT CHARACTERISTICS AS A GUIDE TO APPLICATION, P. E. Benner and G. S. Lunge, General Electric Company.

VOLTAGE REGULATION AND CONTROL IN THE DEVELOPMENT OF A RURAL DISTRIBUTION SYSTEM, G. H. Landis, Central Hudson Gas and Electric Corporation.

THE PERIODIC VOLTAGE SURVEY AS A BASIS FOR DISTRIBUTION DESIGN, R. W. Burrell, Consolidated Edison Company of New York, Inc., and W. E. Appleton, New York and Queens Electric Light and Power Company.

For the purpose of contributing to local discussion, Mr. Brosnan described the practices of the Buffalo, Niagara and Eastern Power Corporation in the matter of voltage control, without attempting to go deeply into supporting material or to make any comparisons of practices followed by other companies. With reference to the characteristics of new load currently being added to distribution systems, Mr. Brosnan emphasized as disturbing points the low power factor and tendency toward rapid load changes, recommending co-operation between electrical manufacturers, electrical contractors, and electric power companies "to insure the proper operation of utilization equipment without interfering with other loads and at the lowest over-all cost to the industry." He recommended as a step in such a co-operative program that power companies should introduce reasonable limitations on motor-starting currents "based on the true capacity of the distribution systems to accommodate such currents without serious voltage disturbance, in place of limitations based on size of motor. He also emphasized the obvious relationship between proper voltage regulation and customer satisfaction.

A brief summary of the characteristics of

Some of those present at the Lenox meeting, left to right: Director K. B. McEachron, chairman of the District meeting committee; H. S. Knowlton of Boston, Mass., National Secretary H. H. Henline of New York, N. Y.; W. H. Timbie, chairman of the Sections committee, of Cambridge, Mass.; Vice-President A. C. Stevens of Schenectady, N. Y.; C. S. Rich, secretary of the technical program committee, of New York; Aram Boyajian, chairman of the Pittsfield Section; and C. A. Read, publicity subcommittee chairman of the District meeting committee

a wide variety of different regulating devices, and a comparison of their suitability for various applications from the manufacturer's viewpoint was presented by Messrs. Benner and Lunge of the General Electric Company. It was their contention that "the majority of systems need both generator voltage regulators and suitable feeder regulators, if maximum ease, efficiency, and flexibility of system operation are desired. Proper choice and adjustment of the voltage-responsive controlling elements of such regulating equipment will insure harmonious functioning of the regulators throughout the system, without hunting between regulators of different construction."

The rapid growth of rural electrification and the importance of maximum service continuity commensurate with economical expenditures has given impetus to the study of means to provide a satisfactory solution, according to Mr. Landis, who described the development of a rural network system in the territory of the Central Hudson Gas and Electric system. He also described methods for obtaining a constant check of voltage conditions throughout a rural area, and stated that the selection of voltage rating for rural lines often is dependent upon operating conditions peculiar to the area served. He expressed the conviction that "with the equipment now available, voltage can be regulated accurately over substantially long lines at reasonable cost, and frequently major expenditures for reinforcement can be deferred for long periods by the proper application of regulating equipment." For many cases of temporary relief he considered the field for application of step regulators to be large because of their low installation cost. Except for unusual conditions, he found little to say in favor of either shunt or series capacitors. He emphasized that rural electrification still is in its infancy with respect to electric power utilization, and "requires continual and careful study in checking of load growth, circuit balance, and voltage regulation to the end of producing greater satisfaction among its users."

Methods of conducting systematic voltage distribution surveys were described by Messrs. Burrell and Appleton, reflecting the practice of the Consolidated Edison Company of New York and the New York and Queens Electric Light and Power Company. Brief reference was made to methods of analysis and application of survey data. The authors consider that a detailed voltage survey need not be made every year; that as voltage conditions are improved a complete survey may be necessary only every two or three years and susceptible of application to different parts of the system in different years. They consider that readings from the systematic voltage survey, "appropriately taken and carefully analyzed, provide the engineering justification for redesign of the distribution system to correct existing unsatisfactory voltage conditions. The periodic survey data, by revealing trends of regulation, make it possible in planning system changes to anticipate unsatisfactory conditions before service voltages actually fall outside the accepted standards of good service. The broad view obtained of system voltage conditions facilitates the consideration of various plans proposed, and is a helpful guide in considering the necessity for general system reinforcement and improvement projects." As between indicating and graphic instruments for such a survey, graphic instruments were favored in studies of rural line voltages and indicating instruments were considered to be "the answer" to voltage survey problems of urban areas. To accommodate conditions arising from shifting load centers, the compensated type of step regulators were considered preferable.

Industrial Application

Representative of the broadening interest in and importance of the increasing penetration of electrical devices into modern industry, were the following four papers which are scheduled for publication in the TRANSACTIONS section of ELECTRICAL ENGINEERING for September:

REGENERATIVE TENSION CONTROL FOR PAPER WINDERS, **H. W. Rogers**, General Electric Company

COMPARISON OF METHODS OF STOPPING SQUIRREL-CAGE INDUCTION MOTORS, **W. I. Bendz**, Westinghouse Electric and Manufacturing Company.

THE APPLICATION OF CAPACITORS FOR POWER-FACTOR CORRECTION IN INDUSTRIAL PLANTS, **C. E. H. von Sothen**, General Electric Company.

PHOTOELECTRIC WEFT-STRAIGHTENER CONTROL, **C. W. LaPierre** and **A. P. Mansfield**, General Electric Company.

Generous in its content of specific operating data of importance to application engineers in the paper mill field was Mr. Rogers' paper descriptive of methods and equipment for meeting the exacting requirements of automatically controlled paper winders. The idea of regenerative tension control is not new, but modernization of the paper industry has stimulated changes and development to meet ever more exacting conditions of operation. This paper also serves to emphasize, quite incidentally, the extent of the needs and possibilities for modern application engineering in other industries such as textile and rubber.

T. H. Morgan of Worcester, Mass., presided at the industrial-applications session

In his comparison of methods of stopping squirrel-cage induction motors, Mr. Bendz presented actual test data in support of his several analyses and detailed conclusions. Each in its turn, he analyzed for different applications the relative advantages of (a) magnetically operated friction braking, (b) plugging, (c) dynamic braking through the application of direct current to one or more of the phase windings of the motor stator, and (d) dynamic braking through the use of a capacitor and resistor in which case the motor functions as an induction generator. Detailed recommendations given should be of special interest to application engineers in the machine tool field. Although test data is limited to motors of ten horsepower or less, the similarity of characteristics of motors up to 40 horsepower or so would permit an extension in the application of data given.

Touching on both the technical and the

Membership—

Mr. Institute Member:

During the past fiscal membership year, 44 out of every 100 applications for membership were obtained from Enrolled Students who desired to become Associate members in the Institute.

This large enrollment of young engineers represents a healthy situation in the Institute affairs. It also offers tangible evidence of the benefits which the Students have received from their Institute associations in the college Branches.

By taking advantage of the liberal policy which the Board of Directors has established for Students desiring to transfer to the Associate grade, these young engineers are enabled to acquaint themselves early with the other members of the electrical profession. Such associations are particularly beneficial to the Section membership and point out the need for close co-operation between Sections and college Branches.

A membership proposal form appears on page 14 of the advertising section of this issue

John Bankus

Vice-Chairman, District No. 9,
National Membership Committee

economic aspects of power-factor correction in industrial plants, Mr. von Sothen described methods of making corrective applications of capacitors. Here again was presented information of especial value to industrial and application engineers. The author gave solutions in some detail for three typical problems involving different energy requirements and rate bases. Discussion brought out the importance in connection with industrial power-factor correction, of giving careful attention to the character of the load of the particular plant, and also of considering future as well as current plant requirements.

In the development of textile machinery and manufacturing methods, the practical operating speed of textile machinery has gone far above the level at which it is possible for human eyes to follow the weave and for human hands to effect the necessary operating control. To the vast improvement of mill efficiency and product quality, the application of photoelectric control equipment, is spreading widely and rapidly. In their description of the photoelectric weft-straightener control, Messrs. LaPierre and Mansfield lucidly described equipment and its operation through which a uniformly square weave with its inherently improved distribution of stresses is obtained. The photoelectric initiating device operates on the scanning principle suggestive of the system used in television.

Transformers—A-C and D-C

Three papers pertained to various transformer problems:

Corona Voltages of Typical Transformer Insulations Under Oil—II, F. J. Vogel, Westinghouse Electric and Manufacturing Company.

New Types of D-C Transformers, C. C. Herskind, General Electric Company.

A D-C Transformer, T. C. Lennox and E. V. DeBlieux, General Electric Company.

These are scheduled for publication in the Transactions section of Electrical Engineering for September.

Referring to earlier work, and especially to that of Doctor L. Dreyfus concerning the matter of transformer insulation design, Mr. Vogel presented experimental data for air and oil and for insulation combinations in oil. Citing that Dreyfus had "assumed that electrical breakdown adjacent to square edges was a function of the stress and the distance over which the stress acted; in other words, that it was a function of the voltage gradient along a line of force for some indeterminate distance, "Mr. Vogel concluded that the work of Dreyfus and the tests reported in his own paper "both show that the arrangement of the insulation at the corners of transformer windings is of great importance to the designer, and that to obtain the greatest strength the area under greatest stress must obviously be free from air. If this condition is obtained, consistent test agreement with the theory for square corners can be obtained, and so-called 'form factors' can be developed for design purposes. Experimental data for one reference condition can be derived which will be useful in general applications, and with 'form factors' it is unnecessary to make countless other tests for every variation in design proportions."

Two different approaches to the problem of accomplishing direct-current transformation were reflected in the papers by Lennox and DeBlieux and by C. C. Herskind. Lennox and DeBlieux described the design of an experimental mechanical commutator for the purpose of transforming direct current from one voltage to another. In effect the experimental device comprised a primary commutator, an intermediate six-phase transformer with static capacitators to control excitation and commutation, and a secondary commutator. The two major cummutator problems were stated as being current collection and commutation. On the basis of experience with the experimental equipment, the authors concluded that "circuit constants and difficulties in mechanical construction have been fairly well explored . . . and the data obtained should be of value in connection with new projects." Experimental developments included a 300-kw 3,000-volt commutator equipment, the underlying motivation for which was a possibility of its application to street railway service to enable a street car to be operated within a city on a 600-volt trolley and to be operated between cities on a 2,400 or 3,000-volt trolley by simply throwing the d-c transformer in or out of the circuit.

Mr. Herskind described the experimental development of both constant-current and constant-potential d-c transformers, using grid-controlled mercury-arc rectifiers. Problems incident to commutation and sequence of circuits are met through the use of the rectifier tubes in place of the mechanical commutator previously mentioned.

A group of students who presented papers at student sessions of the Lenox meeting; left to right: J. T. Bradbury, E. G. Schroeder, Cromwell McIntosh, Jr., D. P. Lacock, R. P. Boyer, Jr., Shepard Roberts, H. B. Abajian, and District Student Chairman F. N. Tompkins

Lightning

Lightning and related phenomena were treated in two papers scheduled for publication in the Transactions section of Electrical Engineering for September:

Multiple Lightning Strokes—II, E. B. McEachron, General Electric Company.

Protector-Tube Application and Performance on 132-Kv Transmission Lines—II, Philip Sporn and I. W. Gross, American Gas and Electric Service Corporation.

Mentioning multiple lightning strokes as having been defined as "a succession of discharges in substantially the same path," Mr. McEachron analyzed the results of some 295 records obtained through the operation of a specially designed oscillograph on the lines of the American Gas and Electric Company at Roanoke, Va. Records seem to indicate that certain storms produce few if any multiple strokes, whereas other storms appear to average about an equal number of single and multiple strokes. As a result of his analyses, Mr. McEachron emphasized that protective equipment should be applied in the light of knowledge that multiple strokes do strike transmission line conductors, and that, if proper protection is to be maintained, devices designed to protect apparatus from the effects of lightning should not include mechanical motions which take time for restoring to normal conditions. Concerning the effect of multiple strokes upon connected apparatus, Mr. McEachron pointed out that on a line without overhead ground-wire protection only the first impulse of the series resulting from a flashover caused by a stroke some distance from the station will be transmitted along the line unaffected by the tower-footing resistance of the flashed structure; succeeding discharges in the stroke will develop potentials in the line dependent upon the IR drop through the tower-footing resistance. He stated also that "where overhead ground wires are used, and strokes do not contact the line conductors, the potential of the traveling wave, both for the first discharge and for succeeding ones will be dependent upon both the footing resistance and the current in the various discharges. Under these conditions, many low-current discharges which are observed upon moving film photographs of direct strokes would not be of serious consequence with reference to connected apparatus. It is at this point that the investigation is probably of greatest value, in that it indicates the number of successive discharges which had sufficient magnitude to cause operation of the protector tubes."

On the basis of an analysis of five years of operating experience with protector tubes on the transmission lines of the American Gas and Electric Company, Mr. Gross drew the following conclusions: that protector tubes, properly installed, protect line insulators against lightning flashover and appear able to operate without mechanical rupture with few exceptions; that protector tubes have reduced line outages more than 50 per cent on the average and

as much as 89 per cent in one instance; that multiple lightning strokes tend to shorten the tube life, and that in general tube life appears to depend largely on the weathering qualities of the exterior of the tube surface; that protective relays on tube-protected lines should have either a definite minimum time of not less than two or three cycles to initiate the tripping of the oil circuit breaker, or, as an alternative when using one-cycle relays, breakers should utilize ultrarapid reclosing.

Student Technical Sessions

Maintaining the District's reputation for active student participation in District meetings, were the 130-odd Enrolled Students registered. The scheduled student program of one technical session accommodating six technical papers, was enlarged to a total of 14 papers by 17 student authors, comprising a full day's schedule of two sessions, the afternoon session of which ran in parallel with the concluding technical session. The student papers presented and generously discussed were as follows:

A Cordless Telephone Switchboard, **R. P. Boyer, Jr.**, University of Maine.

Radio Direction Finders for Boats, **H. B. Abajian**, Rhode Island State College.

Simplified Solution of Differential Equations by Operational Methods, **J. T. Bradbury**, Union College.

Reignition of Short Arcs at High Pressures, **L. P. Winsor**, Harvard University.

A Radio Control for a Moving Vehicle, **D. W. Howe, Jr.**, Worcester Polytechnic Institute.

A Mechanical Analyzer for Composite Waves, **S. H. Monson** and **L. H. McHose**, Cornell University.

Stabilized Regenerative Amplifiers, **Shepard Roberts**, Massachusetts Institute of Technology.

Investigation of Heat Dissipation and Temperature Rises in Underground Ducts, **E. G. Schroeder**, Rensselaer Polytechnic Institute.

Study of Flow of Water Over Narrow Rectangular Weirs, **Cromwell McIntosh**, Union College.

Radio-Wave Polarization, **J. T. deBettencourt**, Harvard University.

Analysis of an Electron-Tube-Controlled Induction Motor, **P. P. Koliss** and **Joseph Ezen**, Worcester Polytechnic Institute.

A Kinetic Device for Determining Synchronous-Machine Characteristics, **A. H. Sullivan, Jr.**, Cornell University.

Electrical Determination of the Roots of Polynomials, **D. P. Lacock**, Massachusetts Institute of Technology.

Impulse-Voltage Investigation, **M. W. Essigmann** and **W. H. Derry**, Tufts College.

Chairman of the morning session was Lucas B. Mayer of Brown University; judges for the morning session were Professor J. D. Cobine of Harvard University, Professor R. G. Porter of Northeastern University, and Professor L. W. Hitchcock, University of New Hampshire. From among the eight papers on the morning program, these judges awarded prizes for most effective presentation as follows: first E. G. Schroeder; second, R. P. Boyer; third, D. W. Howe.

Chairman of the afternoon session was Ewan W. Fletcher of Brown University; judges were District Secretary R. G. Lorraine, Professor A. G. Conrad of Yale University, and Professor J. L. Stiles of Clarkson College. For effective presentation these judges made citations as follows: first, P. P. Koliss and Joseph Ezen; second, D. P. Lacock; third a tie between Cromwell McIntosh and A. H. Sullivan, Jr.

The large number of papers presented, and the necessity for dividing them into two session groups, caused the District committee on student activities to decide to provide duplicate awards for presentation. Subsequent critical examination of the student technical papers will lead to the final District awards which probably will be announced at the 1939 District meeting, tentatively scheduled for Springfield, Mass.

Conference on Student Activities

Under the chairmanship of Professor F. N. Tompkins of Brown University, a luncheon conference was held Friday noon, May 20, for the purpose of discussing problems incident to the conduct of student affairs in the North Eastern District. To fill the post of chairman of the District committee on student activities to be relinquished by Professor Tompkins after two years of service, Professor E. M. Strong of Cornell University was elected. Likewise, Professor A. G. Conrad of Yale University was elected to fill out the personnel of the three-man committee, Doctor E. A Walker of Tufts University continuing to serve. Lengthy discussion of the relative advantages and disadvantages of a student program of a few papers as against a student program of many papers, and of parallel versus tandem sessions, brought a decisive vote in favor of parallel sessions when warranted by the number of papers to be presented. Just what constitutes a desirable number of papers for a student session was left undecided; one school of thought favored rigorous elimination contests that would bring to the District meeting only the one best paper from each school, and the other favored more generous acceptance of a larger number of papers from each school.

Among the 36 persons interested in Student Branch activities who gathered together for the luncheon conference were the following: National Secretary H. H. Henline of New York; Director F. Ellis Johnson of Columbia, Mo.; chairman of the AIEE committee on Student Branches; Vice-President A. C. Stevens of Schenectady; Vice-President-Elect C. L. Dawes of Cambridge; Past Vice-President W. H. Timbie of Cambridge; District Secretary R. G. Lorraine of Schenectady, W. W. Fletcher of Brown University Branch, and Editor G. R. Henninger of New York. Official representatives from 15 of the 16 Student Branches in the North Eastern District present were:

Student Branch Counselors and Alternates

J. D. Cobine, Harvard University, Cambridge, Mass.
B. A. Walker, Tufts College, Medford, Mass.
G. J. Fiedler, Union College, Schenectady, N. Y.
E. M. Strong, Cornell University, Ithaca, N. Y.
A. R. Powers, Clarkson College of Technology, Potsdam, N. Y.
C. D. Knight, Worcester Polytechnic Institute, Worcester, Mass.
R. O Buchanan, University of Vermont, Burlington.
C. W. Henderson, Syracuse University, Syracuse, N. Y.
L. W. Hitchcock, University of New Hampshire, Durham.
O. S. Brown, Massachusetts Institute of Technology, Cambridge.
A. G. Conrad, Yale University, New Haven, Conn.
W. B. Hall, Rhode Island State College, Kingston.
R. G. Porter, Northeastern University, Boston, Mass.
L. C. Holmes, Rensselaer Polytechnic Institute, Troy, N. Y.
F. N. Tompkins, Brown University, Providence, R. I.

Student Branch Chairman and Alternates

L. P. Winsor, Harvard University, Cambridge, Mass.
Roger Burgess, Union College, Schenectady, N. Y.
B. R. Urquhart, Cornell University, Ithaca, N. Y.
C. B. Martin, University of New Hampshire, Durham.
Samuel Carlisles, Jr., Clarkson College of Technology, Potsdam, N. Y.
D. L. Clark, University of Vermont, Burlington.
W. K. Halstead, Massachusetts Institute of Technology, Cambridge.
P. E. Feifert, Rhode Island State College, Kingston.
L. B. Mayer, Brown University, Providence, R. I.
C. R. Kolstad, Northeastern University, Boston, Mass.
E. K. Rice, Rensselaer Polytechnic Institute, Troy, N. Y.
Mortimer Rogers, Syracuse University, Syracuse, N. Y.
B. W. Greeley, Tufts College, Medford, Mass.

District Executive Committee Meets

A luncheon meeting and brief business session of the North Eastern District Executive committee was held Thursday May 19. After a discussion of routine business, unanimous vote was given to a motion to invite the Institute to hold its 1940 summer convention at Swampscott, Mass., in which event there would be no District meeting that year. (The 1939 North Eastern District meeting is scheduled to be held at Springfield, Mass.)

This meeting was attended by the following delegates:

A. C. Stevens, vice-president, AIEE
C. L. Dawes, vice-president-elect, AIEE
R. G. Lorraine, secretary, North Eastern District
F. N. Tompkins, chairman, District committee on student activities
J. L. Cantwell, secretary-treasurer, Pittsfield Section
Edward Carlson, Jr., chairman, Providence Section
W. W. Cotner, secretary, Ithaca Section
R. E. Curtis, secretary-treasurer, Springfield Section
J. A. French, chairman, Connecticut Section
H. A. McCrea, chairman, Boston Section
J. H. Rogers, delegate, Rochester Section
Victor Siegfried, chairman, Worcester Section
W. H. Lawrence, chairman, Syracuse Section

Also in attendance at the meeting were Past Chairman R. F. Chamberlain of the Ithaca Section, Director K. B. McEachron of the Pittsfield Section, and National Secretary H. H. Henline and Editor G. R. Henninger of New York.

Entertainment—Inspection Trips

The Curtis Hotel and the town of Lenox virtually opened their summer season in advance for the purpose of accommodating the 400-odd persons who attended the District meeting. Advantage of natural facilities was taken by the committee in its offering of an unusual variety of entertainment and other special features.

Most unusual feature of the entertainment program was the stag smoker held the first evening, May 18. For the purpose, the Lenox town hall was rechristened "The Gold Nugget Casino" and transported in imagination from its quiet New England setting to the scene of a Western gold mining camp of boom days. Many appropriate

costumes were noted in the crowd (minimum costume requirement for entry was the removal of necktie); the prize for the best costume of the evening went to Past Vice-President W. H. Timbie whose excellent masquerade, however, was somewhat more reminiscent of Casey Jones than of a forty-niner. A hilarious program built around a variety of games and supplemented liberally by a wide variety of refreshments, was brought to a fitting climax in a mock trial of a "cheater" supposedly caught red handed in one of the games.

A total of 185 persons attended the District's annual informal banquet that was given May 18 in the main dining room of the Curtis Hotel with Vice-President A. C. Stevens acting as toastmaster. Continuing the success of an earlier experiment, this affair was not a dinner-dance. Feature speaker of the evening was Past Vice-President W. H. Timbie who spoke at some length on the subject of the engineer's proper place in society, urging engineers to give serious attention to, and to take proper part in, all public questions. Other guest speakers who responded briefly to toastmaster Stevens' remarks were, in the order of their appearance, Director F. Ellis Johnson of Columbia, Mo., President W. H. Harrison, honor guest of the evening, and Vice-President-Elect C. L. Dawes.

During the dinner meeting District Secretary R. G. Lorraine announced the following winners of District prizes for 1937 technical papers, and made awards accordingly: (1) for the best paper, no award; (2) for the best initial paper, Bruce Prentice of the engineering general department of the General Electric Company; (3) for the best Student Branch paper, Abner Crumb, graduate of Worcester Polytechnic Institute and now with the General Electric Company.

A variety of entertainment was offered for women guests, including card parties and drives to nearby points of scenic and historic interest. Of especial interest was a double-header inspection trip through the Sawyer-Regan woolen mill and the Crane paper mill at Dalton. The trip through the woolen mill included observation of the various steps incident to the complete manufacture of high-grade woolen cloth from raw wool to the finished product; likewise tracing raw materials through the paper mill to the ultimate finished product, the inspection group had the privilege of witnessing the manufacture of the special paper which the United States Government uses for paper currency, bonds, etc.—an unusual opportunity to see the original source of a dollar bill.

Principal inspection trips for the men included transformer manufacture for one group and plastics manufacture for another, with a spectacular demonstration of the high-voltage laboratory for both groups—all at the Pittsfield works of the General Electric Company. Through the courtesy of the Stanley Club (General Electric employees club) plans were made for a student dance at the club quarters in Pittsfield following a student dinner at the Curtis Hotel in Lenox, Friday evening, May 20. Conflicting plans of individual students that called for their early return to their individual campuses for seasonal activities reduced the attendance at these two concluding functions to a low level.

AIEE Board of Directors Meets at Headquarters

THE regular meeting of the board of directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, N. Y., May 26, 1938.

Present: *President*—W. H. Harrison, N.Y., *Past-Presidents*—A. M. MacCutcheon, Cleveland, Ohio; J. B. Whitehead, Baltimore, Md. *Vice-Presidents*—O. B. Blackwell, New York, N. Y.; C. Francis Harding, Lafayette, Ind.; I. Melville Stein, Philadelphia, Pa.; A. C. Stevens, Schenectady, N. Y.; Edwin D. Wood, Louisville, Ky. *Directors*—C. R. Beardsley, F. Malcolm Farmer, and C. R. Jones, New York, N. Y.; H. B. Gear, Chicago, Ill.; F. Ellis Johnson, Columbia Mo.; W. B. Kouwenhoven, Baltimore, Md.; K. B. McEachron, Pittsfield, Mass.; C. A. Powel, East Pittsburgh, Pa. *National Treasurer*—W. I. Slichter, New York, N. Y. *National Secretary*—H. H. Henline, New York, N. Y. Present by invitation: John C. Parker, presidential nominee, New York, N. Y.

Minutes were approved of meetings of the board of directors on January 26, 1938, and the executive committee on March 29, 1938.

Actions of the executive committee on applications for election, transfer, and Student enrollment were reported and confirmed, as follows: As of April 14, 1938—475 applicants elected to the grade of Associate; as of April 22, 1938—4 applicants transferred to the grade of Fellow; 9 applicants transferred and 12 elected to the grade of Member; 48 applicants elected to the grade of Associate; 73 Students enrolled.

Reports were presented and approved of meetings of the board of examiners held April 19 and May 12, 1938. Upon the recommendation of the board of examiners, the following actions were taken: 6 applicants were transferred to the grade of Fellow; 20 applicants were transferred and 15 were elected to the grade of Member; 296 applicants were elected to the grade of Associate; 146 Students were enrolled.

Monthly disbursements were reported by the chairman of the finance committee and approved by the board, as follows: $24,797.78 in April; $24,887.08 in May.

In view of the probable effects of the present business recession on Institute membership and income, the board voted "that it is the opinion of the board of directors that every possible attempt should be made to curtail expenditures during the last quarter of the present appropriation year."

A report was presented of the special committee which was appointed, by action of the board of directors in June 1937, to make a recommendation concerning the question of adopting a permanent policy, for inclusion in the by-laws, covering the joint conferences on student activities of Districts 8, 9, and the University of British Columbia Branch, which are usually held in connection with the Pacific Coast conventions of the Institute. The committee recommended that no general rule be adopted, but that each case should be considered on its merits. The board approved the report, and, upon request of the District officers concerned, authorized such joint conference during the 1938 Pacific Coast convention, at Portland, Ore., August 9–12.

To meet changed plans in the arrangement of the summer convention sessions, the board rescinded its resolution of January 26, fixing the date of the 1938 annual meeting of the Institute as Monday, June 20, and adopted a resolution to hold the meeting on Tuesday, June 21, in Washington, D. C.

Approval was given to the dates, November 28–30, 1938, selected by the District officers concerned, for the previously authorized Southern District meeting to be held in Miami, Fla.

The following appointments of Institute representatives, made upon the recommendation of the standards committee, were reported and approved: Professors Ralph D. Bennett and Royce E. Johnson on the sectional committee for revision of the Code for Electricity Meters, *C*-12, and Messrs. J. R. North and C. F. Wagner on the sectional committee on power-line insulators.

A revision in the definition of the scope of activities of the AIEE committee on production and application of light, as recommended by the committee and amended by the technical program committee, was approved, the revised definition reading as follows:

> Treatment of those matters in which the dominant factor is the application of electrical energy through its conversion into light, including necessary materials, devices and mechanisms, in so far as these matters are considered of interest and value to the members of the Institute. This committee functions as a liaison between the Institute and various organizations dealing with the production and utilization of light, such as, the Illuminating Engineering Society, the Optical Society of America, and others. Its activities include translating the theoretical and technical accomplishments of those organizations into terms of the practical aspects of the production and applications of light, thereby serving to inform the Institute members of important progress in this field. Where problems of electric supply service, voltage, or distribution are involved, action shall be joint with the committee on power transmission and distribution.

The report of the committee on award of Institute prizes of prizes awarded for papers presented in 1937 was presented. (An announcement of the prizes awarded was published in the June 1938 issue of ELECTRICAL ENGINEERING, page 262.) The report included a recommendation that a special award be made to an outstanding committee report in the field of engineering practice which was included in the technical program, namely, a report entitled "First Report on Power System Stability," by the subcommittee on interconnection and stability factors of the committee on power transmission and distribution. The board

authorized a special award to this subcommittee report and presentation of a suitable certificate of award.

Upon recommendation of the publication committee, the board authorized that committee to make a survey of the membership, through the columns of ELECTRICAL ENGINEERING, to ascertain the number of members who would be interested in purchasing an up-to-date cumulative index of Institute papers, the latest published index covering the period 1911–1921, and to report its findings to the board of directors.

Mr. G. G. Post was reappointed a representative of the Institute on the Washington Award Commission for the two-year term beginning August 1, 1938.

The resignation of Mr. H. P. Thomas as local honorary secretary of the Institute for India, because of his plans to leave the country next fall, was accepted; and, upon his recommendation and that of the board of examiners, two local honorary secretaries for India were appointed, for the two-year term ending July 31, 1940, as follows: V. F. Critchley for Northern India and N. N. Iengar for Southern India.

The board confirmed the appointment by president of the following committee of tellers to canvass and report upon the election and constitutional amendment ballots: Frederick P. West (chairman), George F. Fowler, Henry Kurz, Edward C. Plant, T. I. Rogers, A. M. Schoettgen, and A. C. Sugden.

Professor V. Karapetoff was appointed the delegate of the Institute to the semicentennial celebration, at Columbia University, New York, N. Y., September 6–9, 1938, of the founding of the American Mathematical Society.

The following amendments to the by-laws were adopted, as the result of the board's action in January in establishing a committee on planning and co-ordination:

Present section 70 cancelled and the following substituted:

Sec. 70. The committee on planning and co-ordination shall consist of the chairmen of the constitution and by-laws, finance, publication, sections, standards, and technical program committees, the national secretary, the chairman who shall be appointed by the president from among the members of the board of directors, and such other members as the president may appoint. The committee may appoint such subcommittees, including other members of the Institute, as may be needed for specific aspects of planning.

The committee shall give continuous attention to the planning of Institute activities for the future, and submit to the Board of Directors reports and recommendations regarding any developments which, in its opinion, would more effectively meet the needs of the membership as a whole, or afford more adequate provisions for specialized types of activities deemed worthy of specific recognition by the Institute.

It shall also consider and advise on all questions arising with reference to Institute activities of all types, particularly those in which uncertainty, difference of opinion, actual conflict, or duplication may appear to exist, whether referred to it by the Board of Directors or otherwise coming to its attention.

The words "committee on planning and co-ordination" substituted for the words "committee on co-ordination of Institute activities" wherever they appear in the by-laws.

The annual report of the board of directors for the fiscal year ending April 30, 1938, as prepared by the national secretary, was submitted for approval for presentation to the membership at the annual meeting in June; and the national treasurer presented a report of Institute finances for the same period.

As required by section 37 of the constitution, consideration was given to the appointment of a national secretary for the administrative year beginning August 1, 1938; and National Secretary H. H. Henline was reappointed.

Other matters were discussed, reference to which may be found in this or future issues of ELECTRICAL ENGINEERING.

New Officers Elected at AIEE 1938 Summer Convention

AT THE annual meeting of the AIEE, held in Washington, D. C., during the Institute's recent summer convention, the report of the committee of tellers on the election of new officers to serve during the year beginning August 1, 1938, was presented. In addition to reporting the results of the election, the committee of tellers also reported the enactment of all the proposed amendments to the AIEE constitution pertaining to admission to the grade of Fellow, which were submitted to the membership for ballot earlier this year. The new amendments become effective 30 days after the annual meeting, or on July 21, 1938.

Three prominent members were honored during the convention. The election of Past-President C. C. Chesney, honorary vice-president of the General Electric Company, Pittsfield, Mass., as an Honorary Member was formally announced; only 33 men previously have been so honored. The AIEE Lamme Medal for 1937 was presented to R. E. Doherty, president of Carnegie Institute of Technology, Pittsburgh, Pa., and former chairman of the AIEE committee on education. The Gaston Planté Medal for 1937, which is the initial award of this medal, was presented by the French ambassador to G. W. Vinal, chief of the section of electrochemistry, National Bureau of Standards, Washington, D. C. A detailed report of the convention is scheduled for the August issue.

The new officers elected were as follows:

President:

J. C. Parker, vice-president, Consolidated Edison Company of New York, Inc., New York, N. Y.

Vice-Presidents:

C. L. Dawes, associate professor of electrical engineering, Harvard University, Cambridge, Mass. (North Eastern District, number 1).

F. M. Farmer, vice-president and chief engineer, Electrical Testing Laboratories, New York, N. Y. (New York City District, number 3).

A. H. Lovell, professor of electrical engineering, assistant dean of college of engineering, University of Michigan, Ann Arbor (Great Lakes District, number 5).

F. C. Bolton, vice-president and dean of the college, Agricultural and Mechanical College of Texas, College Station (South West District, number 7).

L. R. Gamble, electrical engineer, Washington Water Power Company, Spokane (North West District, number 9).

Directors:

L. R. Mapes, chief engineer, Illinois Bell Telephone Company, Chicago, Ill.

H. S. Osborne, transmission engineer, American Telephone and Telegraph Company, New York, N. Y.

D. C. Prince, chief engineer, General Electric Company, Philadelphia, Pa.

National Treasurer:

W. I. Slichter (re-elected) professor of electrical engineering, head of department, Columbia University, New York, N. Y.

The board of directors for the administrative year beginning August 1, 1938, will consist of these newly elected officers, together with the following hold-over officers: W. H. Harrison (retiring president) New York, N. Y.; A. M. MacCutcheon (junior past-president) Cleveland, Ohio; F. Ellis Johnson, Columbia, Mo.; C. R. Jones, New York, N. Y.; W. B. Kouwenhoven, Baltimore, Md.; K. B. McEachron, Pittsfield, Mass.; C. A. Powel, East Pittsburgh, Pa.; R. W. Sorensen, Pasadena, Calif.; C. R. Beardsley, Brooklyn, N. Y.; Vannevar Bush, Cambridge, Mass.; F. H. Lane, Chicago, Ill.; I. Melville Stein, Philadelphia, Pa.; E. D. Wood, Louisville, Ky.; L. N. McClellan, Denver, Colo.; J. P. Jollyman, San Francisco, Calif.; and M. J. McHenry, Toronto, Ont.

The constitutional amendments adopted will alter Section 4 of Article II, and Section 10 of Article III. These sections are quoted in the following paragraphs to show the changes made; *italic* type indicates material added by the amendments, and brackets [ ] indicate deleted material.

ARTICLE II

4. A Fellow shall be not less than 32 years of age and shall be either:

a. An electrical engineer by profession. As such he shall be qualified to design and to take responsible charge of important electrical work; he shall have been in the active practice of his profession for at least ten years, and shall have had responsible charge of important electrical work for at least three years; *and he shall have been in good standing in the grade of Member for a period of at least five years immediately preceding the date of application for Fellow grade.*

When the applicant holds, in a principal national society of an allied branch of engineering, membership of a grade for which the qualifications indicate a standing equal to that required for the grade of Fellow herein, such membership shall be considered equivalent to five of the requisite ten years of active practice of the electrical profession.

b. A professor of electrical engineering or of electrical science. As such he shall have attained special distinction as an expounder of the principles of electrical science and of electrical engineering; he shall have had at least ten years' experience as a teacher of electrical subjects, and shall have had responsible charge for three years, in an electrical course of a principal school of engineering. Any years of experience as defined in paragraph "a" that the applicant may have had as an electrical engineer shall be considered the equivalent of the same number of years of experience as "a teacher of electrical subjects." *He shall have been in good standing in the grade of Member for a period of at least five years immediately preceding the date of application for Fellow grade.*

c. A person who has done notable original work in electrical science of a character to give him a recognized standing equivalent to that required for Fellows under paragraphs "a" and "b."

d. A person regularly engaged in electrical work for at least ten years, who, by inventions or by

special proficiency in contributions to electrical science or the electrical arts or electrical literature, has attained a standing equivalent to that required for Fellows under paragraphs "a" and "b."

c. A person who holds in a principal national electrical engineering society of some other country membership of a grade for which the qualifications indicate a standing equivalent to that required for the grade of Fellow under "a" and "b."

ARTICLE III

10. *Except as otherwise provided in this Article,* application may be made for admission to any grade of membership[. Except as otherwise provided in this Article], *and* applicants shall give references to members of the Institute as follows:

For the grade of Fellow, to five Fellows.
For the grade of Member, to four Fellows or Members.
For the grade of Associate, to three Fellows, Members, or Associates.

Applications for the grade of Fellow shall result only from a proposal of five Members or Fellows, except as to applicants provided for in Article II, Section 4, Clauses c and e. Applications originating from proposals shall comply with the regulations covering admission and transfer as specified in the By-laws.

Applications may be made for transfer from the grade of [Member to the grade of Fellow, or from the grade of] Associate to the grade of Member [or to the grade of Fellow].

Should an applicant for admission or transfer [to any grade] certify that he is not personally known to the above specified number of Fellows, Members, or Associates who are sufficiently familiar with the applicant's experience to justify him in using their names as references, the Board of Examiners may accept, for the deficiency, other references, preferably professional engineers of standing.

South West Student Conference at Kansas State

The 12th annual Student Branch conference of the South West District of the AIEE, held at Kansas State College, Manhattan, May 6–7, was one of the largest ever held in the District, from the standpoint of attendance. Fourteen student Branches from the following schools were represented:

University of Arkansas, Fayetteville.
Kansas State College, Manhattan.
University of Kansas, Lawrence.
University of Missouri, Columbia.
Missouri School of Mines, Rolla.
University of New Mexico, Albuquerque.
Oklahoma Agricultural and Mechanical College, Stillwater.
University of Oklahoma, Norman.
Rice Institute, Houston, Texas.
Southern Methodist University, Dallas, Texas.
Agricultural and Mechanical College of Texas, College Station.
Texas Technological College, Lubbock.
University of Texas, Austin.
Washington University, St. Louis, Mo.

The longest distance traveled by any of the delegations to reach Manhattan was by the one from the University of New Mexico who reported the distance as around 840 miles; 98 students outside of Manhattan were in attendance, the largest number being from the University of Kansas and from Texas Technological College, each having 15 at the conference. The total attendance of students was 200, which together with 28 faculty members and counselors, made a grand total of 228. In addition, the conference was attended by L. T. Blaisdell (A'20, M'22), vice-president of the South West District, L. C. Starbird (A'32, M'35), secretary of the District, and Dean F. E. Johnson (A'13, F'31) director of AIEE.

In general the conference was considered to be one of the most successful ever held in the district; 22 technical papers were presented, and all the schools but one participated in the presentations. The papers represented a high order of technical effort and were well received by the group. The papers given were as follows:

POWER FACTOR IN UNBALANCED POLYPHASE CIRCUITS, **B. G. Philpott** and **R. F. Johnson**, University of Missouri.

DETERMINATION OF STRAY-LOAD LOSSES IN DIRECT-CURRENT MACHINES, **D. J. Evans** and **Thomas McKale**, University of Kansas.

VERTICAL DIRECTIVITY APPLIED TO BROADCAST ANTENNAS, **W. D. White**, Missouri School of Mines.

PROPELLER FANS, **Sydney Black**, Washington University.

AN IMPROVED METHOD OF OBTAINING RETARDATION DATA, **J. R. Kelling**, Agricultural and Mechanical College of Texas.

CATHODE-RAY CURVE TRACER FOR AUDIO AMPLIFIERS, **Warren L. Spielman**, Washington University.

PENTODE VACUUM TUBES AS VOLTAGE AMPLIFIERS, **Andrew Hilderbrand**, Southern Methodist University.

THE EFFECT OF CURRENT WAVE DISTORTION ON ENERGY MEAUREMENTS, **H. N. Stafford**, University of Texas.

THE NEUTRAL CURRENT SIGNALING SYSTEM, **Francis W. Ringer**, University of Oklahoma.

AN INVESTIGATION OF THE PERFORMANCE OF CIRCUIT BREAKERS TO REPLACE FUSES, **W. E. Graber** and **R. F. Horrell**, University of Kansas.

THE LOAD-BUILDING RANGE, **S. LeR. Bradley**, Oklahoma Agricultural and Mechanical College.

ELIMINATION OF AUTOMOBILE HEADLIGHT GLARE, **Lyle Donaldson**, Texas Technological College.

A CATHODE-RAY ENGINE INDICATOR, **James Roark**, University of Arkansas.

DUAL-CURRENT ELECTRIC PLANTS, **Russell E. Phillips**, Kansas State College.

DIRECTIVE ANTENNA ARRAYS, **Loyd Dorsett**, University of Oklahoma.

VARIABLE SPEED-CONSTANT TORQUE OPERATION OF INDUCTION MOTORS, **F. K. Spragins**, Rice Institute.

WAVE GUIDES AND STANDING WAVES, **W. W. Mieher** and **H. J. Zimmerman**, Washington University.

WHY "ULTRA-HIGH?" **J. Y. Bowman**, Southern Methodist University.

SERIES CAPACITORS, **Richard Poletsky**, Washington University.

AN INSTRUMENT FOR THE RESOLUTION OF VECTORS INTO SYMMETRICAL COMPONENTS, **F. D. Witt**, Rice Institute.

WIND-DRIVEN FARM ELECTRIC PLANTS, **Edward Smith** and **Veari Huff**, Kansas State College.

HIGH-FIDELITY INSTANTANEOUS RECORDING, **R. W. Matthews**, Missouri School of Mines.

In awarding positions of merit of the papers the judges found a tie for first place between the papers by B. G. Philpott and R. F. Johnson, University of Missouri, and W. D. White, Missouri School of Mines. Second place was awarded to the paper by H. N. Stafford, University of Texas. The winners will receive conference certificates as prizes of merit.

At the banquet held on Friday evening Doctor F. D. Farrell, of Kansas State, extended greetings and a hearty welcome to the visitors. Short talks were given by Dean Johnson of the University of Missouri, and by L. C. Starbird. The address of the evening was given by L. T. Blaisdell, in which he voiced the importance of membership in professional technical societies because of its value to the individual and the engineering profession.

After the banquet the students adjourned to the college dance hall where "dates" had been provided for the visitors; 100 couples attended the dance.

Following the technical session on Saturday, a luncheon and business meeting was held for the counselors at which Professor N. F. Rode, of Texas Agricultural and Mechanical College was elected chairman of the counselors for the coming year, succeeding Professor Chester Russell, Jr., of the University of New Mexico. A luncheon and round-table discussion also were held for the student chairmen.

Transformer Subcommittee Discusses Standards

At a meeting of the transformer subcommittee of the AIEE committee on electrical machinery held May 20, 1938, at Lenox, Mass., during the recent AIEE North Eastern District meeting, the proposed American Standard on transformers, regulators, and related matters was discussed. I. W. Gross, chairman of the subcommittee has made available the following report of actions taken.

The following outstanding objections were raised to the proposed Standard in its present form:

1. The Standard should be issued separately, and the appendix, test code, and recommendations for operation also should be a separate publication.
2. In its present form the proposed Standard is entirely too voluminous and contains a large amount of material not required in this type of Standard.
3. The standardization of transformer sizes, taps, etc., does not properly belong in a Standard of this type.
4. The text of the manual should be free from any mandatory requirements for operation of equipment; and if suggestions and operating procedure are made at all, they should not be in the Standard but rather in the second publication (test code, etc.).
5. There is entirely too much duplication in the present setup, and this should be eliminated.

A sub-subcommittee of four members was appointed to go over the proposed transformer standard and report back at the next meeting of the subcommittee. In the meantime, it is understood that no action will be taken to put the proposed standard into force.

The subject of front-of-wave test was discussed and progress reported, although definite decision was not reached as to desirable rates of voltage rise, methods of measurement, and definite specification in accordance with voltage classes of equipment.

The subject of impulse testing with 60-cycle excitation on the transformer also was discussed, and some difference of opinion was expressed as to the necessity of having the transformer excited when being impulse-tested. The majority favored retaining the test, although it was pointed out that some complications in commercial testing could be avoided if the 60-cycle excitation were omitted. It was not definitely shown from the discussion that 60-cycle excitation on equipment under impulse test is a definite means of locating equipment failures if such occur. The matter will be discussed further at a subsequent meeting of the subcommittee.

Report of the Board of Directors

THE board of directors of the American Institute of Electrical Engineers presents herewith to the membership its 54th annual report, for the fiscal year ending April 30, 1938. A general balance sheet showing the condition of the Institute's finances on April 30, 1938, together with other detailed financial statements, is included herein. This report contains a brief summary of the principal activities of the Institute during the year, more detailed information having been published from month to month in ELECTRICAL ENGINEERING.

BOARD OF DIRECTORS' MEETINGS

During the year, the board of directors held five meetings, four in New York City, and one at Milwaukee, Wis. The executive committee meetings in December and March were held in place of regular meetings of the board. Information regarding many of the more important activities of the Institute which have been under consideration by the board of directors and the committees is published each month in the section of ELECTRICAL ENGINEERING devoted to "News of Institute and Related Activities."

PRESIDENT'S VISITS

President Harrison attended the Pacific Coast and winter conventions and the Middle Eastern District meeting. He also visited many Sections and some Student Branches. During May and June, President Harrison will attend the North Eastern District meeting in Lenox, Mass., and the summer convention in Washington, D. C., and make a few other visits.

The places visited are listed below:

California
Los Angeles Section
San Francisco Section

Colorado
Denver Section

Illinois
Urbana (District conference on student activities)

Indiana
Central Indiana Section, Lafayette
Fort Wayne Section
Purdue University, Lafayette

Iowa
Iowa Section, Des Moines

Louisiana
New Orleans Section

Michigan
Detroit-Ann Arbor Section, Detroit

Minnesota
Minnesota Section, Minneapolis

Missouri
Kansas City Section
St. Louis Section

Nebraska
Nebraska Section, Omaha

New York
New York Section
Winter Convention
Pratt Institute, Brooklyn

North Carolina
North Carolina Section, Chapel Hill

Ohio
Akron Section
Cincinnati Section
Columbus Section
Ohio State University, Columbus

Oklahoma
Oklahoma City Section

Pennsylvania
Lehigh Valley Section, Wilkes-Barre
Philadelphia Section
Pittsburgh Section

Tennessee
Memphis Section

Texas
Dallas Section
Houston Section

Washington
Spokane (Pacific Coast Convention)

Wisconsin
Milwaukee (Summer Convention)

Canada
Toronto Section

NATIONAL CONVENTIONS

Three national conventions were held during the year, and a brief report on each follows:

Summer Convention. The 53d summer convention was held in Milwaukee, Wis., June 21–25, 1937. During 10 technical sessions, 35 technical papers, 5 committee reports, and 3 addresses were presented. Two technical conferences were held: one on field problems, and the other on electrical apparatus for three-phase arc furnaces. Convention events of unusual interest were a lecture by Doctor Vannevar Bush on Tuesday evening, an address by Doctor R. E. Flanders during the first part of the general session on Wednesday morning, and the subsequent introductory discussions by six members on various phases of Institute programs, which were followed by general discussion.

Other parts of the convention were the annual business meeting, conference of officers, delegates, and members, president's reception, followed by dinner and dancing, boat trip on Lake Michigan, buffet supper and smoker, golf and tennis tournaments, ladies' events, and farewell gathering. The registration was 1,067.

Annual Meeting. The annual business meeting of the Institute was held on Monday morning, June 21, as part of the opening session of the summer convention. The annual report of the board of directors for the fiscal year which ended April 30, 1937, was presented in abstract by the national secretary. A report on the finances of the Institute was presented by National Treasurer W. I. Slichter. The report of the committee of tellers upon the election of officers for the year beginning August 1, 1937, was presented, and President-Elect Harrison responded to his introduction with a brief address.

Pacific Coast Convention. The 25th Pacific Coast convention was held in Spokane, Washington, August 31 to September 3, 1937, with a registration of 266. Six technical sessions, two student sessions, a joint conference on student activities, reception and dancing, a banquet, inspection trips, a golf tournament, and ladies' events constituted the principal features of the convention. One of the technical sessions was held jointly with the Institute of Radio Engineers.

Winter Convention. The 26th winter convention was held in New York City, January 24–28, 1938, with a technical program including 66 papers in 16 sessions, 4 technical conferences, and 3 addresses. During a general session on Wednesday morning, brief addresses were given by President Harrison, and T. F. Barton, chairman of the winter convention committee, the Alfred Noble Prize was presented to Doctor G. M. L. Sommerman, and Doctor H. G. Moulton, president of the Brookings Institution, gave an address on "Technological Development in Relation to Economics."

At an evening session, the Edison Medal was presented to Past President Gano Dunn; and Stephen F. Voorhees, senior partner of Voorhees, Gmelin and Walker, gave an illustrated lecture on the "New York World's Fair, 1939."

A smoker, numerous inspection trips, and ladies' events completed the program of the convention which had a registration of 1,438.

DISTRICT MEETINGS

Brief reports on the two District meetings held during the year are given below.

North Eastern District Meeting. This meeting was held in Buffalo, N. Y., May 5–7, 1937, with five sessions, including one for student papers, a dinner and a second evening meeting, each with a talk and demonstration, a District conference on student activities, inspection trips, and ladies' events. The registration was 352.

Middle Eastern District Meeting. The meeting of this District was held in Akron, Ohio, October 13–15, 1937, with seven technical sessions, including one for the presentation of student papers, a banquet, dinner and entertainment at Nela Park, inspection trips, conference on student activities, and ladies' events. The registration was 464.

SECTIONS

The Sections maintained unusually keen interest in their activities during the past year. The total number of meetings reported was slightly larger than the number for 1936–37, which far exceeded that for any previous year. Interest in technical groups and other forms of more specialized meetings continued strong, and special efforts were made in some Sections to determine the particular interests of their membership with reference to subjects.

As usual, a considerable number of Sections offered prizes for the best papers presented in competition, and the interest in encouraging student participation in Section programs produced several excellent joint meetings with Branches.

Three new Sections were organized during the year: Wichita in September, Tulsa in October, and Muscle Shoals in February, and each took its place among the more active Sections. These brought the total number to 65.

The name of the Atlanta Section was changed to Georgia Section, and its territory was extended to include the entire state.

Table I. Section and Branch Statistics

	For Fiscal Year Ending			
	April 30, 1932	April 30, 1934	April 30, 1936	April 30, 1938
Sections				
Number of Sections	60	61	61	65
Number of Section meetings held	497	472	540	624
Total attendance	105,325	73,271	85,501	110,148
Branches				
Number of Branches	109	113	118	120
Number of Branch meetings held	1,135	1,015	1,045	1,334
Total attendance	54,197	41,772	45,304	60,446

The Sections committee completed a year's study of the various Section activities in an endeavor to facilitate co-operation between Sections, and to enable the Sections to serve their communities more effectively. Self-analysis blanks were filled out by the Sections, and the results were studied by a subcommittee. The findings of this study were published in the March issue of ELECTRICAL ENGINEERING, pages 134–5.

The Sections committee also made a compilation of the various plans which the different Sections are using in dealing with the local membership problems. A detailed outline was prepared of the more successful plans, and a copy was sent to each Section. The object of this study was to aid the Sections in settling satisfactorily their individual problems concerning local membership.

More detailed information on these activities may be found in the annual report on Section and Branch activities in the June issue of ELECTRICAL ENGINEERING, pages 263–3.

STUDENT ACTIVITIES

A new Branch organized at Northwestern University brought the total number to 120. A large majority of the Branches carried on a substantial amount of activity, but two reported no meetings. The total number of meetings reported was below that for the preceding fiscal year, but larger than the total for any previous fiscal year.

The extensive participation by students in the technical programs of national conventions and District meetings was continued, student sessions having been held as follows: North Eastern District meeting in Buffalo, one, Pacific Coast convention in Spokane, two, and Middle Eastern District meeting in Akron, one.

With the endorsement of the chairman of the committee on Student Branches, the committee on safety sent a letter of October 30, 1937, to the counselors of all Student Branches suggesting that each Branch have presented "a paper dealing with some phase of the problem of the prevention of accidents or remedial measures after an electrical shock." Twenty-four Branches followed this suggestion.

The terms of enrollment of 1,474 Students expired on April 30, 1938, and 703, or about 48 per cent, applied for admission as Associates.

SECTION AND BRANCH STATISTICS

Data on the Sections and Branches are given in table I.

TECHNICAL PROGRAM COMMITTEE

The general review and study of the planning, scope, and procedures of the programs of Institute meetings, which had been carried out during the previous year, resulted in two changes which have been put into effect in the course of the current year and which are believed to be important forward steps.

Advance Copies of Technical Papers. A subcommittee of the technical program committee, under the chairmanship of R. N. Conwell, as a result of their study, recommended last July that "the Institute adopt as a policy the provision of preprints of technical articles submitted as program material." This proposal had been made by the publication committee, and was discussed and approved at the conference of officers, delegates, and members held at the summer convention in Milwaukee. The recommendation was approved by the new technical program committee appointed the first of August, by the publication committee, and, in October 1937, by the board of directors. As a corollary to this recommendation, ELECTRICAL ENGINEERING is relieved of the necessity of publishing all technical papers, but will include about two-thirds of them. The TRANSACTIONS will in the future include all of the formal technical program papers rather than consisting of a reprinting of ELECTRICAL ENGINEERING as in recent years.

The change to the new procedure has been carried out gradually during the year, and the summer convention in Washington will be the first meeting at which the new policy is completely effective. At the winter convention in January, advance copies were provided for 39 out of 65 papers, the others having previously been published in ELECTRICAL ENGINEERING. The advance copies are sold at a nominal price (in addition to a limited free distribution). The response of the membership has been good, and it is anticipated that the average distribution of 212 copies of the advance copies of winter convention papers (not including quantity orders, averaging 40 copies per paper) will be increased as the plan becomes fully effective and as the membership becomes accustomed to it.

General Meetings. The "special committee on Institute activities" arranged for a meeting of broad general interest at the summer convention in Milwaukee, to which a half day was devoted without parallel sessions. At this meeting, Doctor Ralph Flanders addressed the Institute on the subject "The Engineer in A Changing World." This was followed by a discussion by members of the Institute on the subject "How Can Institute Programs Be Made of Greatest Value to the Membership?" This discussion evoked so much interest that it was continued in the afternoon of the following day.

Based upon this experience, the special committee on Institute activities recommended to the board of directors that while "major emphasis should continue to be given to the technical programs substantially along the present lines," the programs of Institute meetings should frequently include "sessions at which subjects of general interest to all the members are discussed." This recommendation was approved by the board in August 1937, and the technical program committee has been guided by it in the programs for the current year.

At the winter convention Doctor Harold G. Moulton, president of the Brookings Institution, Washington, presented an address on "Technological Development in Relation to Economics." His penetrating analysis of this subject proved of great interest to the membership. At the approaching summer convention in Washington, arrangements have been made for a general session to which Wednesday morning will be devoted, at which the Institute will be addressed by Doctor W. R. Gregg, chief of the Weather Bureau, and Colonel J. M. Johnson, assistant secretary of the Department of Commerce on aeronautics. Also, at the business meeting on Tuesday morning, it is hoped that an address will be given on municipal planning in Washington, by an appropriate official.

Technical Programs. Certain information regarding the technical programs for the national conventions and District meetings for the current year in comparison with the previous year is given in table II.

These figures show a marked increase in the Institute's activity. The increase in registration at national conventions and District meetings is especially striking. There was one more convention this year than last (the Pacific Coast convention and summer convention having been combined in 1936), but, even after allowances for that fact, the registration has increased by 20 per cent.

Attention is called to the material decrease in the average length of paper which is, the committee believes, a worth-while achievement. Engineering papers tend to be too long for maximum effectiveness, and in many cases the approval of a paper is delayed by the process of having it shortened. It is hoped that authors will co-operate with the technical committees and the technical program committee in continuing this trend toward shorter papers.

Table II. Technical Programs, Last Two Years

	April 30, 1937 to April 30, 1938	April 30, 1936 to April 30, 1937
Number of sessions	43	37
Number of conferences	8	10
Number of papers presented	155	124
Registration at national conventions and District meetings	3,590	2,720
Average length of paper, pages	6½	7½

In comparison with a budget of 1,115 pages for the previous appropriation year, the technical program committee is operating this year on a budget of 1,200 pages of papers recommended for the TRANSACTIONS plus provision for duplicating in small quantities 300 pages of additional material for presentation only. Because of the change in the publication procedure associated with the provision of advance copies for technical meetings, a considerable part of the expense of publishing this year's technical papers will go over into next year's budget. In the approval of papers, however, the technical program committee has laid its plans on the basis of adhering to the allotted budget, since the carry-over of publication expense will, of course, affect next year's budget.

The satisfactory results of the year's work and the real progress which has been made have come about through the loyal cooperation and devoted efforts of the chairmen of the technical committees, the members of the technical program committee, and of other committees co-operating with them, and the untiring zeal of Mr. Rich and other members of the staff involved in the work of the committee.

PUBLICATION COMMITTEE

During the year, there has been put into effect the revised publication policy approved by the board of directors at its October 28, 1937, meeting, and described on page 1409 of the November 1937 issue of ELECTRICAL ENGINEERING. This revised policy has made it possible not only to meet more fully the diversified interests of the membership with reference to ELECTRICAL ENGINEERING and TRANSACTIONS, but also to make available in advance photolithographic copies of manuscripts of technical program papers, and to shorten the time required to make technical program papers available for distribution; all of this, of course, within the limitation of the publication budget. Also a real improvement has been made in the efficiency of operation of the publication office.

At the 1938 winter convention, over 3,600 separate advance copies of technical program papers were sold, and practically all of the comments received with reference to the arrangement as a whole and with reference to the form of the advance copies have been favorable.

One feature of the revised publication policy is that discussions are correlated with their respective papers, both in the TRANSACTIONS section of ELECTRICAL ENGINEERING and in the bound annual volume of TRANSACTIONS. While the new policy was made effective, in general, with the January 1938 issue of ELECTRICAL ENGINEERING, the full effect of the new policy will not be evident until the issuance of the September 1938 number. The change from prepublication of technical program papers in ELECTRICAL ENGINEERING to postpublication naturally could not be made completely in any one issue. Beginning with the April 1938 issue, the discussions are correlated with all the technical program papers published. However, until the September issue, there will appear separate discussions pertaining to technical program papers which were published before the discussions became available.

Table III. Membership Statistics for the Fiscal Year Ending April 30, 1938

	Honorary	Fellow	Member	Six-Year Associate	Associate	Total
Membership on April 30, 1937	10	709	4,118	5,791	4,680	15,308
Additions						
Transferred	1	25	151	614		
New members qualified		1	167	39	1,428	
Former members reinstated		2	14	27	19	
	11	737	4,450	6,471	6,127	17,796
Deductions						
Died	2	16	34	29	11	
Resigned		4	37	153	120	
Transferred		1	17	149	624	
Dropped		6	46	185	284	
	2	27	134	516	1,039	1,718
Membership on April 30, 1938	9	710	4,316	5,955	5,088	16,078

The improved efficiency in the publication office is permitting more attention to be given to the publishing of a suitable proportion of general interest articles in ELECTRICAL ENGINEERING. This is a continuation of the policy outlined in last year's report.

Early in the year there was brought to a satisfactory conclusion the publication of the "Lightning Reference Book." The attempt to handle this matter on a self-supporting basis was entirely successful, and the form and appearance of this volume have received very favorable comment. As a result of the success of this venture, consideration is being given to the publication of other books on a similar self-supporting basis.

In recognition of the duties and responsibilities he has been carrying regularly for a number of years, F. A. Norris was appointed business manager of ELECTRICAL ENGINEERING, effective November 15, 1937. This involved no change in the salary account of the publication office.

MEMBERSHIP COMMITTEE

The membership committee has continued its activity along lines similar to those of the last few years. An active national committee of 21 members and Section committees or representatives in all of the Sections have continued their work throughout the entire year. Two meetings of the national committee were held in New York, one being at the time of the winter convention to permit a large percentage of the committee to be present.

Continuing the policy of last year in passing along increased responsibility to the District vice-chairmen of the committee, it was recommended, and the board of directors approved the proposal, that the vice-chairmen become members of their respective District executive committees. The vice-chairmen, supported by their respective Section membership committeemen, have worked in close contact with each other to produce a good record for the year.

The general business conditions now affecting a large portion of the industrial areas in the country have had their effects upon the membership returns, as will be noted in table IV wherein it is seen that the total number of applications received is slightly smaller than last year. The hard work of the Section committees has done much to prevent a smaller figure appearing in this column. It is interesting to note in the same table that the applications received from students has, however, slightly increased over last year, in spite of the current economic conditions. The strong efforts made by the committees to induce Enrolled Students whose terms were expiring to apply for admission as Associates has been largely responsible for this figure not falling below last year's report. Though the total number of applications received is less than last year, it must be said, in all fairness, that seven of the ten Districts returned more applications than they did for the year 1936–37.

In spite of the decrease in the number of applications received, the total membership of the Institute has been increased by 770 members. This makes the total membership 16,078, as compared with 15,308 one year ago. This compares with the 708 increase for last year. The number of members dropped during the year, due to failure to meet Institute requirements, was 521, as compared with 526 last year.

Table V shows an interesting increase in the number of Enrolled Students. These men form a very important source of new members for the Institute each year.

Table IV. Number of Applications Received From Enrolled Students and From All Others

Year Ending	From Students	From All Others	Total
April 30, 1938	739	932	1,671
April 30, 1937	716	1,040	1,756
April 30, 1936	631	946	1,577
April 30, 1935	575	715	1,290
April 30, 1934	467	496	963

Table V. Number of Enrolled Students

April 30, 1938	5,037 (2,428)
April 30, 1937	4,503 (2,249)
April 30, 1936	4,049 (1,991)
April 30, 1935	3,806 (1,983)
April 30, 1934	3,186 (1,548)

Following the number of Students reported for April 30 of each year is indicated within parentheses the number of new applications received during that year; the difference between this number and the reported total, of course reflects the number of renewals of Student enrollment for the corresponding period.

Table VI. Number of Members in Section Territory Reinstated

August 1, 1937 to April 30, 1938	306
Year beginning August 1, 1936	503
Year beginning August 1, 1935	663
Year beginning August 1, 1934	831
Year beginning August 1, 1933	741

Table VI indicates a decrease in the number of former members who have been reinstated in Section territory. The number of delinquent members available for reinstatement has been decreasing continuously, which, of course, accounts for the smaller number reinstated each year, but it is also probable that present economic conditions have had their effects in further decreasing the number this year. It will be noted that the figure 306 applies to a nine-month period. The figure for the same months last year was 460.

It is encouraging to note that the record of members who have their dues fully paid as of April 30th has again increased slightly in spite of the conditions now existing. This is shown in table VIII.

Although the Institute's membership is still somewhat less than the peak reached in 1927—see table IX—it has been continually increasing since the low figure of 1935 reached as an effect of the business depression.

Deaths

The following deaths occurred during the year:

Honorary Members: Guglielmo Marconi, Ambrose Swasey.

Fellows: Philip P. Barton, Byron B. Brackett, Kay A. Christiansen, Clarence L. Cory, Maurice Costa, David F. Crawford, Henry W. Fisher, George E. Hayler, Samuel E. M. Henderson, John W. Howell, Arthur L. Mudge, Peter W. Sothman, Edwin R. Stoekle, Charles W. Stone, Joseph A. Thaler, Norman T. Wilcox.

Members: Harry A. Baker, Clifford W. Bates, Norman M. Baxter, Bennett M. Brigman, Charles Brossman, Frank D. Burr, E. R. Carichoff, Walter Cary, E. S. Code, James A. Correll, H. Milton Dearmin, Edgar D. Edmonston, William B. Folline, Edwin P. Harder, H. Lester Harris, Joseph A. Hepp, William M. Joy, Albert B. Junkins, Emil M. Kaegi, Charles Max, William F. McLaren, Theodore B. Morgan, Edward L. Nichols, Edward J. Pratt, Frank B. Rae, Charles P. Randolph, Ralph T. Rossi, Howard T. Sands, Carl G. Schluederberg, James F. Schnabel, Carroll Shipman, Arthur Townsend, Henry H. Vrooman, Henry H. Wait.

Associates: David C. Bacon, Maurice Barrere, Max A. Berg, Robert C. Brown, Francis E. Cabot, Charles L. Cadle, Paul A. Callis, Robert A. Connor, L. W. Copeland, Harry G. Cotter, Frank L. Dalas, Alfred W. Dater, Lucius F. Deming, Robert J. Deneen, E. A. Enquist, Milton M. Gess, Joseph Goodman, Russell S. Gueffroy, William G. Heptinstall, Edward W. Judy, Emil E. Keller, Thomas H. Kettig, Robert King, Hugh Lesley, Mrs. Zella A. McBerty, George E. McLean, Winfred Morrill, Albert J. J. Murphy, William M. O'Brien, Joseph H. Paget, John Pearson, Benjamin Robinson, William G. Rogers, Michael Romano, Banka A. Roy, Henry W. Taylor, Robert Taylor, Wilbur S. Werner, Philip B. Woodworth, George R. Wright.

Committee on Transfers

The committee on transfers gave intensive consideration to the development of desirable methods of encouraging members who are qualified for the higher grades to submit applications for transfer.

The following paragraphs were prepared by the committee for inclusion (with modifications to conform to any amendments to constitution and by-laws that may be adopted) in the general letter sent to Section officers in September of each year by the national secretary:

"The officers of each Section should consider the matter of encouraging members of the Institute who are fully qualified for the higher grades to submit their applications for transfer, and should set up in their Section means for such encouragement. The means should be appropriate to the situation in the Section. A Section committee on transfers consisting of three or five older men (Fellows and Members), who know the Section membership well, is probably the best. Such a committee continuing on from year to year will come to know the situation and can act with discretion. The Section membership committee can no doubt be of considerable help in this work, especially in encouraging Associate to Member transfers.

"The regulations covering transfer will be found in the constitution, sections 10–14, 16, and by-laws, sections 2–4, 7–9, 13.

"Any questions which any group has should be referred to H. E. Farrer, secretary, board of examiners, AIEE, 33 West 39th Street, New York, N. Y."

Table X contains the numbers of applications for transfer to the grades of Fellow and Member recommended and not recommended by the board of examiners during the past 12 years.

Board of Examiners

The board of examiners held 11 meetings during the past year, averaging about two and one half hours each, and considered 3,956 cases, divided as shown in table XI.

Standards Committee

The report of the standards committee of a year ago reflected a considerably increased activity in the standardization field. That general high level has continued throughout the year just ended. Several Institute committees have been carrying on much preliminary development work later to be submitted to American Standards Association as the basis of American standards. Likewise, the sectional committees working under ASA procedure have brought to completion many projects that now have the full status of American standards.

At this point, it might be advisable to call attention to an action taken at the October 1937 meeting of the standards committee. A recommendation was made to the directors at that meeting, and later approved by them, suggesting the carrying out by the Institute's technical committees of a survey of the entire electrical standardization field. Such a survey, it was felt, would be the most effective way of determining what fundamental standardization should be under way and how the Institute could most effectively continue to play its rightful part in such work. Concrete indications of the results of the recommendation made are now becoming apparent, although no evidence of fundamental standardization overlooked has been uncovered in any survey reported to date.

A statement of actual detailed actions taken by the standards committee during the year will not be attempted here, as those actions are all matters of record. In general, it has been necessary to make many new committee appointments, because the work of many sectional committees has reached a stage calling for reorganization, and others long inactive have become active. Certain changes in sponsorship of sectional committees also have taken place.

During the year, two Institute standards, "Relays" and "Automatic Stations," received in revised form the approval of ASA as American standards. Likewise, it was deemed desirable for the Institute to give official approval to the publication of a revision of its existing standard for "Oil Circuit Breakers." This action was taken in order to place immediately in the hands of industry many new data on breakers developed by the committee on protective devices. The revised standard, it is understood, will eventually become part of the American standard for "Oil Circuit Breakers" now in course of development by the sectional committee on power switchgear.

The standards committee put into operation a recommendation received from the committee on co-ordination of institute

Table VII. Membership of the Institute, April 30, 1938

Of the 16,078 members reported for April 30, 1938, 14,127 are fully paid to April 30, 1938. The balance of 1,951 are divided into the following groups:

1. Members owing dues to April 30, 1937. Total number of members who have not acted upon resolution of board of directors adopted in January 1938 providing an extension of time for payment of these dues	470
2. Members owing dues to April 30, 1938	1,481

(During the period May 1 to 17, 1938, 270 members have paid dues to April 30, 1938, reducing the total to 1,211.)

Table VIII. Memberships Fully Paid

	Membership as of April 30	Number of Members Fully Paid as of April 30	Per Cent Fully Paid
1938	16,078	14,127	87.9
1937	15,308	13,439	87.8
1936	14,600	12,446	85.2
1935	14,269	11,512	80.5
1927 (year of maximum membership)	18,344	16,247	88.5

activities calling for the organization of a subcommittee to consider the electrical characteristics of bushings. As it is planned to make the personnel of this committee inclusive of all interested groups, it is felt their report will eventually be generally acceptable.

At the February meeting, one subject was discussed, which may prove of great interest to the entire electrical industry. It was suggested that consideration be given to a possible revision of many of the established ideas on the rating of all types of electrical machinery. There would be involved such questions as temperature endurance limits of insulating materials, the classification of new materials, methods of temperature measurement, and rating versus performance under operating conditions. As the first step in the proper approach to these questions, it was agreed that if possible a symposium should be arranged at an Institute convention calling for a thorough discussion of the points outlined, together with the presentation of related data. Arrangements for a symposium are now under way.

United States National Committee of the IEC

Although no plenary meeting of the International Electrotechnical Commission was held during the past year, meetings of seven advisory committees were held. These covered: section *B* on transformers of advisory committee No. 2 on rating of electrical machinery; No. 8 on standard voltages and currents and high voltage insulators, with special relation to impulse voltages; No. 9 on electric traction equipment; No. 13 on electrical measuring instruments; No. 22 on electronic devices; No. 12 on radio-communications; and No. 7 on aluminum. In addition, a meeting of the committee of action of the IEC was held, at which a number of important decisions with respect to the work of the IEC were taken.

It will be recalled that last year it was reported that consideration was being given to international standardization on acoustics. After full discussion in the committee of action, the IEC decided to recommend that the International Standards Association (ISA) be invited to undertake the general organization of the standardization work in the field of acoustics, the IEC being ready to co-operate with the ISA through an advisory committee on electroacoustics. This recommendation was accepted by the ISA, and a meeting was held in Paris in June 1937 at which a number of important decisions were taken. The most important of these had to do with the acceptance of the American reference level for sound measurements of 10^{-16} watts per square centimeter, thus making this effectively a world standard.

The committee of action also undertook a study of the most effective manner of handling within the IEC standardization work on co-ordination of insulation. The various advisory committees concerned have been contacted and the opinion of the various national committees sought. A decision in the matter will be taken shortly.

New IEC projects on electric welding—No. 26—and electroheating—No. 27—have been initiated recently.

New Publications. New publications issued during the past year include a new IEC specification for a-c circuit breakers (Publication No. 56) which covers definitions, rules for rating, and rules for type tests for a-c circuit breakers; an appendix to IEC Publication No. 46 on steam turbines covering supplementary notes to section 4 of instruments and methods of measurement of the rules for acceptance tests. Also a draft of a revised edition of Publication No. 38 on standard voltages was issued.

International Vocabulary—No. 1. The International Electrotechnical Vocabulary, which it was expected would be available during the past year, entailed so much work that it was not possible to have the first edition ready for distribution. It is now hoped, however, that it will be available before the end of the current year.

Radio Interference. Several meetings of the international special committee on radio interference were held, and a considerable volume of work done concerning the methods of measuring radio noise which are used in the different countries. This work has resulted in the development of a standard measuring apparatus which is being manufactured in Belgium and sold to the various countries interested. Consideration is being given in this country to securing this apparatus for test in this country. After the results obtained by the use of this apparatus are available to the international special committee, discussions of the results on a comparable basis will be possible.

Plenary Meeting. A plenary meeting of the IEC is now scheduled to be held in Torquay and London, England, June 22 to July 1. At this time meetings of 21 advisory committees, as well as of the international committee mixed on traction, the committee of action and the council of the IEC will be held. As would be expected, much of the work of the advisory committees during the past year has been devoted to preparations for this complete series of meetings. The United States national committee will be well represented, its total delegation probably numbering about 22 individuals, including the president and secretary of the USNC. In addition, James Burke, the president of the IEC, who is an American, will be in attendance.

Committee on Safety

In line with the change in the by-laws of the Institute, the committee on safety has, with an enlarged program, replaced the committee on safety codes which had been in existence for a number of years, and had rendered valuable service to the Institute. It was felt that the time had come to enlarge the functions of this committee and hence the change in the by-laws and organization were approved.

The committee held three meetings during the year, and has instituted a program based primarily on education. Through co-operation with the appropriate committees of the Institute, letters were forwarded to the counselors of Student Branches and to the chairmen of Sections, recommending that during the year at least one meeting should be devoted to the reception and discussion of a paper dealing with some phase of safety or remedial measures after electrical shock. As a result of these letters, a considerable number of Student Branches and Sections have had papers presented to them and interesting discussions of these papers have taken place. In the case of other Sections and Student Branches, their programs for

Table IX. Record of AIEE Membership

Total Membership May 1		Total Membership May 1		Total Membership May 1	
1884	71	1903	2,229	1921	13,215
1885	209	1904	3,027	1922	14,263
1886	250	1905	3,460	1923	15,298
1887	314	1906	3,870	1924	16,455
1889	333	1907	4,521	1925	17,319
1890	427	1908	5,674	1926	18,158
1891	541	1909	6,400	1927	18,344
1892	615	1910	6,681	1928	18,265
1893	673	1911	7,117	1929	18,133
1894	800	1912	7,459	1930	18,003
1895	944	1913	7,554	1931	18,334
1896	1,035	1914	7,876	1932	17,550
1897	1,073	1915	8,054	1933	17,019
1898	1,098	1916	8,202	1934	15,200
1899	1,133	1917	8,710	1935	14,269
1900	1,183	1918	9,282	1936	14,600
1901	1,260	1919	10,352	1937	15,308
1902	1,549	1920	11,345	1938	16,078

Table X. Applications for Transfer During the Past 12 Years

Year Ending April 30	Fellow Grade Recommended	Fellow Grade Not recommended	Fellow Grade Total	Member Grade Recommended	Member Grade Not recommended	Member Grade Total
1927	30	5	35	293	32	325
1928	21	3	24	280	17	297
1929	45	2	47	229	19	248
1930	28	2	30	211	29	240
1931	44	3	47	322	31	353
1932	7	2	9	149	17	166
1933	29	2	31	109	11	120
1934	25	2	27	154	3	157
1935	19	2	21	199	23	222
1936	27	1	28	205	24	229
1937	24	2	26	167	27	194
1938	26	0	26	137	7	144
Totals	325	26	351	2,455	240	2,695

Table XI. Applications for Admission and Transfer

Applications for Admission		
Recommended for grade of Associate	964	
Re-elected to the grade of Associate	119	
Not recommended	16	1,099
Recommended for grade of Member	140	
Re-elected to the grade of Member	28	
Not recommended	34	202
Recommended for grade of Fellow	1	
Re-elected to the grade of Fellow	—	
Not recommended	1	2
Applications for Transfer		
Recommended for grade of Member	159	
Not recommended	11	170
Recommended for grade of Fellow	31	
Not recommended	—	31
Students		
Recommended for enrollment as Students		2,452
Total		3,956

the year were completed when the committee's letter was received, but arrangements have been made that the matter will receive consideration during next year. From the letters received from the Sections which had these papers presented to them, it is quite apparent that there is a very active interest in this subject among the members and among the students.

Letters to professors of electrical engineering in some 120 universities and colleges were sent out, recommending that at least the senior students receive instruction and training in artificial respiration, as they would be required to have this knowledge on entering industry. As a result of these letters, active training of senior students has been either increased or instituted in more than half of these colleges. As a result of the answers to these letters, it was found that, in some colleges and universities, courses in accident prevention are carried out, in some instances on a voluntary basis, but in other instances being required for the degree. The committee is very appreciative of the general co-operation given by the professors of electrical engineering.

Arrangements are on foot to have presented to the Institute papers on specific subjects dealing with the prevention of accidents. One paper that has been generally requested is at present in preparation.

Representatives of the committee have attended meetings of the National Fire Waste Council, the National Fire Protection Association, and a meeting of representatives of safety committees in engineering associations called by the engineering section of the National Safety Council.

In laying down a basic principle, the committee feels that a design to be efficient must be safe to construct, operate, and maintain, and that electrical engineers not only deal with material things, but also are in many cases responsible for the organization; training, and direction of men in the construction, installation, and operation of plant and equipment. For this reason, they are vitally interested in the protection of these men from accident.

Every endeavor has been made in carrying out the work of the committee to keep it practical and on a sound foundation upon which more extensive programs can, in the future, be built.

Co-ordination Committee

In addition to its duties concerned with the national and District meetings referred to it by the board of directors, the committee has given serious attention, at the request of the president, to the problem of long range planning for the Institute as a whole. It has recommended to the board a reconstitution of the committee, to be called the committee on planning and co-ordination, and alterations in the by-laws which would assign to this new committee the task of long range planning studies, with particular reference to the interests of special groups within the Institute membership, as well as the responsibilities of the present committee.

Institute Policy Committee

The Institute policy committee was appointed in accordance with the requirements in the by-laws, and was ready to consider any matters that might be brought to its attention. However, the board of directors did not find it necessary to refer any questions to the committee.

Committee on Code of Principles of Professional Conduct

The committee has undertaken no revision of the code and no proposals of this sort have been submitted to the committee.

Committee on Constitution and By-Laws

This committee conducted its work by correspondence, and considered and recommended several proposed amendments to the constitution and by-laws of the Institute.

Committee on Economic Status of the Engineer

The committee has met at convenient times during conventions. The committee members have also carried on correspondence relating to the work of the committee. At a meeting held during the winter convention, the committee had for discussion a considerable amount of data, largely in the form of bulletins published by the Bureau of Labor Statistics of the United States Department of Labor. Also the committee had available, by virtue of C. F. Scott's membership on the committee, the accumulated experience of Engineers' Council for Professional Development. As data available were reviewed and discussed, the chairman of the committee made the remark: "The economic status of the engineer is largely a matter determined by each individual engineer according to his particular personal qualifications and the relations these bear to the work he does and to the personalities of those persons with whom and by whom he is employed." Whereupon he was instructed by the committee to write a paper setting forth the reasons leading to the comment made. That paper has been submitted to the technical program committee for use at the summer convention in June, and may be referred to as a part of this report.

Committee on Award of Institute Prizes

Four national and 12 District prizes were awarded in 1937 for papers presented in the calendar year 1936 and for student papers presented during the academic year ending June 30, 1937. These awards were announced in the issues of Electrical Engineering for June, September, October, and November 1937.

The committee considered a large number of papers and the gradings and recommendations of the technical committees which had reviewed the papers. Many papers considered were of a high quality, and, in addition to the national prizes, ten other papers were given honorable mention.

Copies of a revised edition of the pamphlet "National and District Prizes," containing revisions recommended by the committee and approved by the board of directors, were distributed in August 1937.

Committee on Award of Columbia University Scholarships

During February and March 1937, 15 inquiries regarding Columbia University scholarships were received from interested students in some ten institutions. Application forms and information were sent to each of these, but not a single formal application for the scholarship was received.

This is ascribed to the fact that, during May and June 1937, the industries made such a demand for technical graduates that all Columbia University graduates obtained positions in industry immediately upon graduating, and many had been engaged long before commencement.

Edison Medal

The Edison Medal, which is awarded by a committee composed of 24 members of the Institute, was, for 1937, awarded to Gano Dunn "for distinguished contributions in extending the science and art of electrical engineering, in the development of great engineering works, and for inspiring leadership in the profession," and was presented on January 26, 1938, during the winter convention. The medal may be awarded annually "for meritorious achievement in electrical science, electrical engineering, or the electrical arts."

John Fritz Medal

The John Fritz Medal board of award, composed of representatives of the national societies of civil, mining, mechanical, and electrical engineers, awarded the 34th medal (for 1938) to Doctor Paul Dyer Merica, vice-president, International Nickel Company, for "important contributions to the development of alloys for industrial uses."

Lamme Medal

The Lamme Medal committee awarded the medal for 1937 to Doctor Robert E. Doherty, president, Carnegie Institute of Technology, "for his extension of the theory of a-c machinery, his skill in introducing that theory into practice, and his encouragement of young men to aspire to excellence in this field." Arrangements are being made for the presentation of the medal at the annual summer convention in Washington, D. C., June 20–24, 1938. The medal may be awarded annually to a member of the AIEE "who has shown meritorious achievement in the development of electrical apparatus or machinery."

Alfred Noble Prize

This prize, established in 1929, consists of a certificate and a cash award of $500 from the income from a fund contributed by engineers and others to perpetuate the name and achievements of Alfred Noble, past-president of the American Society of Civil Engineers and of the Western Society of Engineers. It may be made to a member of any of the co-operating societies, ASCE, AIME, ASME, AIEE, or WSE, for a technical paper of particular merit accepted by the publication committee of any of these societies, provided the author, at the time of such acceptance, is not over 30 years of age. The award for 1937 was presented to Doctor

G. M. L. Sommerman, research engineer, American Steel & Wire Company, Worcester, Mass.

Washington Award

The Washington Award for 1938 was bestowed upon Doctor Frank B. Jewett, for "inspiring and directing scientific research leading to improvements in the art of communication," and was presented to him at a dinner on May 5, 1938. This award may be made annually to an engineer by the commission of award composed of nine representatives of the Western Society of Engineers and two each of the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, and AIEE.

Hoover Medal

The Hoover Medal was established through a trust fund created by a gift from Conrad N. Lauer, and is to be awarded periodically "to a fellow engineer for distinguished public service" by a board representing the national societies of civil, mining and metallurgical, mechanical, and electrical engineers. The last award was made to Doctor Ambrose Swasey in 1936.

Iwadare Foundation Committee

No Iwadare lecturer was chosen to go to Japan for the current year. One Iwadare fellow, Kiyoshi Abe, assistant professor of Kyoto Imperial University, is at present in the United States.

Employment Service

The Institute co-operates with the national societies of civil, mining, and mechanical engineers in the operation of the Engineering Societies Employment Service with its main office in the Engineering Societies Building, New York. Offices are operated in Chicago and San Francisco also. In addition to the societies named, others co-operate in certain of the offices as follows: New York—Society of Naval Architects and Marine Engineers; Chicago—Western Society of Engineers; San Francisco—California Section of the American Chemical Society; and the Engineers' Club of San Francisco.

The service is supported by the joint contributions of the societies and their individual members who are benefited. In addition to the publication of the employment service announcements monthly in Electrical Engineering, weekly subscription bulletins are issued for those seeking positions.

An analysis of this employment service as reported to the national societies is given in table XII.

Table XII. Analysis of Employment Service

Month	Men Registered				Men Placed			
	New York	Chicago	San Francisco	Total	New York	Chicago	San Francisco	Total
1937								
May	288	82	89	459	51	32	25	108
June	310	99	108	517	53	33	26	112
July	233	92	59	384	50	34	16	100
August	206	82	53	341	49	31	25	105
September	205	77	64	346	54	22	16	92
October	212	71	74	357	51	18	22	91
November	185	97	80	362	48	8	12	68
December	179	91	66	336	34	3	13	50
1938								
January	244	90	73	407	37	10	10	57
February	216	58	68	342	30	8	17	55
March	237	96	101	434	33	8	16	57
April	229	135	92	456	25	9	17	51
Total	2,744	1,070	927	4,741	515	216	215	946

American Engineering Council

The American Engineering Council has continued its activities in the wide range of affairs which are found within the scope of its objectives: "to further the public welfare wherever technical and engineering knowledge and experience are involved, and to consider and act upon matters of common concern to the engineering and allied technical professions," and within the interests of its many member-bodies.

The 18th annual meeting of the assembly was held in Washington, D. C., January 13–15, 1938. The eighth conference of engineering society secretaries was held on the 13th.

The four major themes occupying the attention of the assembly were the engineer's economic status, the evaluation of technology, planning of public and private enterprise, and government reorganization. Reports of officers and standing and special committees were presented. Much attention was given to efforts to clarify the objectives and procedures of the Council in order to give engineers a more definite place in the consideration of public questions.

The discussions and actions at the annual meeting and subsequent actions by the executive committee gave the Council a modified program for 1938, consisting of the five principal functions:

I. Public Affairs—Contacts between the engineering profession and the federal government.

II. Public Discussion—Holding of forums, in co-operation with member bodies, for discussion of public problems involving engineering.

III. Engineers' Embassy—Service to members on engineering matters involved in federal government activities.

IV. Publicity—Regular reporting upon above mentioned functions to member bodies.

V. Fact Finding—Surveys and investigations to determine the effects of technology upon employment, relation of engineering to economics in public questions, etc.

A more complete statement of the 1938 program may be found in the May 1938 issue of Electrical Engineering, page 228, and accounts of activities in progress appeared in various issues of that publication during the past year.

United Engineering Trustees, Inc.

This organization manages the Engineering Societies Building and administers certain joint funds for the four founder societies. The American Institute of Chemical Engineers has moved its headquarters into the building, which is now fully occupied.

Provisions have been made for the resumption of annual additions to the depreciation and renewal fund.

A new edition of the "History, Charter, and By-laws" was issued in 1937.

An abstract of the annual report of the United Engineering Trustees, Inc., was published in Electrical Engineering for December 1937, page 1529.

Engineering Foundation

The Engineering Foundation is a joint organization of the national societies of civil, mining and metallurgical, mechanical, and electrical engineers established for "the furtherance of research in science and engineering, and the advancement in any other manner of the profession of engineering and the good of mankind."

The foundation suffered a serious loss in the death of Doctor Ambrose Swasey, its founder, on June 15, 1937.

The foundation has been assisting in a wide range of technical researches sponsored by the founder societies. Some of the principal groups now in progress are: ASCE—soil mechanics and foundations, hydraulics; AIME—alloys of iron, barodynamic problems; ASME—critical pressure steam boilers, fluid meters, lubrication, cottonseed processing, plasticity; AIEE—stability of impregnated paper insulation; AIEE and AWS—welding; University of California—plastic flow of concrete.

Assistance in nontechnical matters related to engineering has been granted to the Engineers' Council for Professional Development and the Personnel Research Federation.

An abstract of the annual report of the Engineering Foundation was published in the December 1937 issue of Electrical Engineering, pages 1529–30.

Engineering Societies Library

The Engineering Societies Library, which was formed by combining the separate libraries of the four national societies of civil, mining and metallurgical, mechanical, and electrical engineers, and the preparation of a composite card catalog, has been expanded as a single engineering library, which probably constitutes the best collection of this type of literature in the United States.

On September 30, 1937, the library had 141,193 volumes, 7,281 maps, and 4,362 bibliographies. Books, pamphlets, and maps totaling 11,003 were received during

the year ending at that time. Current issues of 1,416 periodicals were received. Work progressed rapidly on a classified index to periodicals, and the index now contains more than 187,000 references to articles published since 1927.

Special services rendered by the library include: photoprints, searches, abstracts, translations, bibliographies, book loans by mail, etc.

An abstract of the annual report of the library was published on page 1530 of ELECTRICAL ENGINEERING for December 1937.

ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT

This council was organized in 1932 to engage in activities leading to the enhancement of the professional status of the engineer. It includes three representatives of each of the seven participating organizations: the national societies of chemical, civil, electrical, mechanical, and mining and metallurgical engineers, the Society for the Promotion of Engineering Education, and the National Council of State Boards of Engineering Examiners.

The principal activities of ECPD include programs for the guidance of young individuals thinking of entering the engineering field, the accrediting of curricula of engineering schools, encouragement and assistance to individuals in their engineering and cultural studies during several years after graduation, and the development of criteria for indicating the attainment of the status of an engineer.

At the annual meeting held on October 1, 1937, many additional curricula of engineering schools were accredited, bringing the total number to 445 in 107 schools. The complete list appeared in the November 1937 issue of ELECTRICAL ENGINEERING, page 1418. Seventy-one of the 445 curricula were accredited for limited periods, and will be re-examined as those periods expire. Prior to the date of the annual meeting, the committee on engineering schools had prepared recommendations on 626 curricula in 129 institutions.

Comprehensive excerpts from the reports of the committees on student selection and guidance, engineering schools, and professional training as presented at the annual meeting were published in the November 1937 issue of ELECTRICAL ENGINEERING, pages 1416–19. The report of the committee on professional recognition was referred back to the committee.

At its meeting held on October 28, 1937, the board of directors of the Institute disapproved the recommendations of ECPD: (1) That the minimum definition of an engineer adopted by ECPD be applied as a minimum requirement for admission to the professional grades of membership, and evidence of professional education also be required; and (2) that membership grades be adjusted to conform to the ECPD standard grades of membership.

REPRESENTATIVES

The Institute has continued its representation upon many joint committees and national bodies, with which it co-operates in a wide range of activities of interest and importance to engineers and others.

A list of representatives was published in the September 1937 issue of ELECTRICAL ENGINEERING and in the 1938 Year Book.

FINANCE COMMITTEE

The committee, as usual, recommended a detailed budget to the board of directors, passed upon the expenditures for various purposes, made recommendations regarding delinquent members, and performed the other duties prescribed for it in the constitution and by-laws.

Haskins and Sells, certified public accountants, have audited the books, and their report follows.

The year has been so productive of constructive work throughout every activity of the Institute that the board of directors extends to the District and Section officers, the national committees, and the membership its sincere appreciation of their continuing interest, untiring efforts, and effective services.

Respectfully submitted for the board of directors.

H. H. HENLINE,
National Secretary

May 26, 1938

HASKINS & SELLS
CERTIFIED PUBLIC ACCOUNTANTS

22 EAST 40TH STREET
NEW YORK

May 24, 1938

American Institute of Electrical Engineers,
33 West 39th Street,
New York,

Dear Sirs:

We have made an examination of your balance sheet as of April 30, 1938, and of your recorded cash receipts and disbursements for the year ended that date. In connection therewith, we examined or tested your accounting records and other supporting evidence in a manner and to the extent which we considered appropriate in view of your system of internal accounting control. We present the following financial statements:

Balance Sheet, April 30, 1938 (Exhibit A).
Property and Restricted Funds Securities, Less Reserve for Securities of Doubtful Value (Schedule 1).

Statement of Recorded Cash Receipts and Disbursements of General Fund for the Year Ended April 30, 1938 (Exhibit B).

Statement of Recorded Cash Receipts and Disbursements of Property and Restricted Funds for the Year Ended April 30, 1938 (Exhibit C).

In accordance with the terms of our engagement, members and other debtors were not requested to confirm to us the amounts receivable from them at April 30, 1938, and, in accordance with the usual practice of the Institute, no provision has been made for dues which may prove to be uncollectible.

In our opinion, based upon such examination and subject to the comments in the foregoing paragraph, the accompanying Exhibit A fairly presents your financial condition at April 30, 1938, and the accompanying Exhibits B and C set forth your recorded cash receipts and your disbursements of funds, as indicated, for the year ended that date.

Yours truly,

HASKINS & SELLS

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Exhibit A — **Balance Sheet, April 30, 1938**

ASSETS			LIABILITIES		
Property Fund Investments:			Property Fund Reserve		$554,507.10
One-fourth interest in real estate and other assets of United Engineering Trustees, Inc., exclusive of trust funds	$498,448.48		**Restricted Fund Reserves:**		
Equipment:			Reserve Capital Fund	$192,002.66	
Library—volumes and fixtures	37,296.37		Life Membership Fund	9,121.52	
Office furniture and fixtures (less reserve for depreciation, $28,749.43)	5,695.90		International Electrical Congress of St. Louis Library Fund	5,357.82	
Works of art, etc.	3,001.35		Lamme Medal Fund	4,578.03	
Securities—at cost (market quotation value, $8,997.53)—Schedule 1	10,042.53		Mailloux Fund	1,044.73	
Cash (see Exhibit C)	22.47		Total restricted fund reserves		212,104.76
Total property fund investments		$554,507.10	Current Liabilities—Accounts Payable		6,079.74
Restricted Fund Investments:			**Deferred Income:**		
Securities—at cost (market quotation value, $180,615.66) less reserve for securities of doubtful value—Schedule 1	$206,824.65		Dues received in advance	$ 4,509.21	
Cash (see Exhibit C)	5,070.95		Entrance fees and dues advanced by applicants for memberships	659.04	
Accrued interest receivable	209.16		Deferred credits and other unallocated receipts	444.82	
Total restricted fund investments		212,104.76	Subscriptions for TRANSACTIONS received in advance	40.00	
Current Assets:			Reserve for prepaid subscriptions for ELECTRICAL ENGINEERING	8,500.00	
Cash (see Exhibit B)	$ 49,616.89		Total deferred income		14,153.07
Accounts receivable:			Surplus		66,778.90
Members—for dues	18,753.01				
Advertisers	140.00				
Miscellaneous	2,124.39				
Accrued interest on investments	2,591.98				
Inventories:					
TRANSACTIONS, etc.	2,082.25				
Text and cover paper	7,231.60				
Work in process (May issue of ELECTRICAL ENGINEERING)	3,443.04				
Badges	1,028.55				
Total current assets		87,011.71			
Total		$853,623.57	**Total**		$853,623.57

Property and Restricted Funds Securities, Less Reserve for Securities of Doubtful Value, April 30, 1938

Exhibit A, Schedule 1

	Face Value of Bonds or Number of Shares of Stock	Property Fund (Equipment Replacement)	Restricted Funds: Reserve Capital Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund	Total
Railroad Bonds:								
Alleghany Corporation 20-year collateral trust convertible 5%, due 1949	$15,000.00	$	$ 10,627.50					$ 10,627.50
Baltimore & Ohio Railroad Company 6% refunding and general mortgage series C, due 1995	12,000.00		8,940.00			$4,330.00		13,270.00
Central of Georgia Railway Company 5% consolidated mortgage, due 1945	3,000.00		1,477.50					1,477.50
Chicago, Burlington & Quincy Railroad Company 5% first and refunding mortgage series A, due 1971	1,000.00		1,010.00					1,010.00
Chicago & Erie Railroad Company 5% first mortgage, due 1982	1,000.00		1,105.00					1,105.00
Chicago & Northwestern Railway Company 6½%, due March 1, 1936	9,000.00		7,202.50					7,202.50
Cleveland Union Terminals Company 5% sinking fund series B, due 1973	4,000.00	$ 4,010.00						
Florida East Coast Railway Company 5% first and refunding mortgage series A, due 1974 (certificates of deposit)	10,000.00		9,818.75					9,818.75
New York Central Railroad Company 5% refunding and improvement mortgage series C, due 2013	6,000.00		5,742.50					5,742.50
Northern Pacific Railway Company 6% refunding and improvement mortgage series B, due 2047	10,000.00		10,962.50					10,962.50
Pennsylvania Railroad Company 30-year secured serial 4%, due 1944	6,000.00		5,337.50		$1,067.50			6,405.00
St. Louis-San Francisco Railway Company 5% prior lien mortgage series B, due 1950 (certificates of deposit)	6,000.00		5,497.50					5,497.50
Southern Pacific Company Oregon Lines 4½% first mortgage series A, due 1977	1,000.00				996.25			996.25
Texas and Pacific Railway Company general and refunding series B 5%, due 1977	5,000.00			$5,306.25				5,306.25
Western Pacific Railroad Company 5% series A, due 1946 (stamped)	15,000.00		7,225.00					7,225.00
Total railroad bonds—(Forward)		$ 4,010.00	$ 74,946.25	$5,306.25	$2,063.75	$4,330.00		$ 86,646.25

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Property and Restricted Funds Securities, Less Reserve for Bonds of Doubtful Value, April 30, 1938

Exhibit A, Schedule 1 (Concluded)

	Face Value of Bonds or Number of Shares of Stock	Property Fund (Equipment Replacement)	Restricted Funds: Reserve Capital Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund	Total
TOTAL RAILROAD BONDS—(Forward)		$ 4,010.00	$ 74,946.25	$5,306.25	$2,063.75	$4,330.00		$ 86,646.25
Public Utility Bonds:								
American Gas & Electric Company 5% debenture, due 2028	$ 9,000.00		$ 9,596.25					$ 9,596.25
Georgia Power Company first and refunding mortgage 5%, due 1967	10,000.00		9,725.00					9,725.00
Monongahela-West Pennsylvania Public Service Company 6% debentures, due 1965	8,000.00		8,660.00					8,660.00
New York Telephone Company first and general mortgage 4½%, due 1939	1,000.00						$1,000.00	1,000.00
Philadelphia Company secured 5% series A, due 1967	10,000.00		10,000.00					10,000.00
Texas Electric Service Company 5% first mortgage, due 1960	10,000.00		9,838.75					9,838.75
Total public utility bonds			$ 47,820.00				$1,000.00	$ 48,820.00
Industrial and Miscellaneous Bonds, Etc.:								
Fidelity Union Title and Mortgage Guaranty Company first mortgage certificates (on property 75–79 Prospect Street, East Orange, N. J.), 4%, due 1944	$14,663.00	$ 977.53	$ 13,685.47					$ 13,685.47
General Motors Acceptance Corporation 3¼%, due 1951	7,000.00		7,140.00					7,140.00
New York Steam Corporation 6% first mortgage, due 1947	10,000.00		10,837.50					10,837.50
Total industrial and miscellaneous bonds, etc.		$ 977.53	$ 31,662.97					$ 31,662.97
Municipal Bonds:								
City of Detroit public lighting 4½% series A, due 1945	$10,000.00		$ 10,262.50					$ 10,262.50
New York City 4½% corporate stock, due 1957	2,000.00				$2,204.05			2,204.05
Total municipal bonds			$ 10,262.50		$2,204.05			$ 12,466.55
United States Government Bonds and Notes:								
Federal Farm Mortgage 3%, due 1949/44	$12,000.00		$ 12,405.00					$ 12,405.00
Treasury Bonds 3¼%, due 1941	10,000.00		10,550.00					10,550.00
Treasury Bonds 2¾%, due 1947/45	10,000.00		10,409.38					10,409.38
Treasury Notes 2% series B, due September 15, 1942	8,000.00		8,037.50					8,037.50
Total United States Government bonds and notes			$ 41,501.88					$ 41,501.88
Capital Stocks:								
Commonwealth Edison Company	48 shares		$ 2,892.00					$ 2,892.00
Commercial Investment Trust Corporation 4¼% preferred, series of 1935	100 "		10,100.00					10,100.00
Consolidated Edison Company of New York, Inc. $5.00 cumulative preferred	30 "	$ 3,060.00						
International Match Realization Co., Ltd. voting trust certificates for capital shares of International Match Corporation	6 "		2,319.15					2,319.15
Public Service Corporation of New Jersey $5.00 preferred	30 "		2,958.75					2,958.75
United Gas Improvement Company $5.00 preferred	30 "	1,995.00	997.50					997.50
Total capital stocks		$ 5,055.00	$ 19,267.40					$ 19,267.40
Total		$10,042.53	$225,461.00	$5,306.25	$4,267.80	$4,330.00	$1,000.00	$240,365.05
Less Reserve for Securities of Doubtful Value:								
Central of Georgia Railway Company 5% consolidated mortgage, due 1945	$ 3,000.00		$ 1,477.50					$ 1,477.50
Chicago & Northwestern Railway Company 6½%, due March 1, 1936	9,000.00		7,202.50					7,202.50
Florida East Coast Railway Company 5% first and refunding mortgage series A, due 1974	10,000.00		9,818.75					9,818.75
International Match Realization Company, Ltd. voting trust certificates for capital shares of International Match Corporation	6 shares		2,319.15					2,319.15
St. Louis-San Francisco Railway Company 5% prior lien mortgage series B, due 1950	$ 6,000.00		5,497.50					5,497.50
Western Pacific Railroad Company 5% series A, due 1946 (stamped)	15,000.00		7,225.00					7,225.00
Total reserve for bonds of doubtful value			$ 33,540.40					$ 33,540.40
Total securities, less reserve		$10,042.53	$191,920.60	$5,306.25	$4,267.80	$4,330.00	$1,000.00	$206,824.65
Total Property Fund Securities		$10,042.53						
Total Restricted Fund Securities			$191,920.60	$5,306.25	$4,267.80	$4,330.00	$1,000.00	$206,824.65

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Statement of Recorded Cash Receipts and Disbursements of General Fund for the Year Ended April 30, 1938

Exhibit B

Cash on Deposit With the National City Bank of New York, May 1, 1937		$ 51,700.32
Receipts:		
Dues (including $84,762.00 allocated to ELECTRICAL ENGINEERING subscriptions)	$193,344.84	
Advertising	34,842.44	
TRANSACTIONS subscriptions	7,278.99	
ELECTRICAL ENGINEERING subscriptions	14,483.41	
Miscellaneous publications, etc.	12,237.45	
Student fees	12,340.50	
Entrance fees	7,798.02	
Membership badges	1,849.21	
Transfer fees	870.00	
Interest on investments, less purchased interest	9,446.50	
Miscellaneous	495.07	
Total receipts		294,986.43
Total		$346,686.75
Disbursements:		
Publication expense:		
ELECTRICAL ENGINEERING	$ 89,285.12	
TRANSACTIONS	6,125.37	
Preprints—technical papers	2,228.72	
YEAR BOOK	6,452.59	
Miscellaneous publications, etc.	8,437.87	
Institute meetings	13,537.95	
Institute Sections	34,130.54	
Institute Branches	2,671.66	
Edison Medal committee	197.46	
Finance committee	1,600.00	
Headquarters committee	95.25	
Membership committee	7,642.85	
Standards committee	6,827.46	
Technical committee	171.96	
Forward	$179,404.80	$346,686.75

Total—(Forward)		$346,686.75
Disbursements—(Forward)	$179,404.80	
Traveling expenses:		
Geographical Districts:		
Executive committees	1,947.77	
Vice-presidents	246.03	
Branch counselors	6,550.60	
President's appropriation	821.76	
Board of directors	4,396.59	
National nominating committee	1,062.55	
Administrative expenses	45,564.12	
Geographical Districts—best paper prizes	141.50	
Geographical Districts—initial paper prizes	26.50	
National prizes	6.00	
American Engineering Council	12,000.00	
American Standards Association	1,500.00	
United Engineering Trustees, Inc.:		
Building assessment	11,022.64	
Library assessment	9,313.83	
Library stacks	1,500.00	
Engineering Societies employment service	1,332.96	
Engineers' Council for Professional Development	415.00	
John Fritz Medal	50.00	
National Fire Protection Association—dues	60.00	
United States Committee of International Commission on Illumination	300.00	
Membership badges	1,650.85	
Legal services	250.00	
Retirement salary	2,250.00	
Miscellaneous	256.36	
Transfers to reserve capital fund	15,000.00	
Total disbursements		297,069.86
Cash on Deposit With The National City Bank of New York, April 30, 1938		$ 49,616.89

Statement of Recorded Cash Receipts and Disbursements of Property and Restricted Funds for the Year Ended April 30, 1938

Exhibit C

		Restricted Funds					
	Property Fund (Equipment Replacements)	Reserve Capital Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund	Total Restricted Funds
Cash on Deposit, May 1, 1937, With East River Savings Bank and The National City Bank of New York	$22.47	$ 306.40	$4,546.42	$ 938.62	$137.33	$48.92	$ 5,977.69
Receipts:							
Interest on bonds, and dividends on stocks			$250.00	$175.00	$240.00	$45.00	$710.00
Interest on bank balances			71.27				71.27
Proceeds from sale of securities		$33,417.54					33,417.54
Life membership fees			404.09				404.09
Transfers from general fund		15,000.00					15,000.00
Total receipts		$48,417.54	$ 725.36	$ 175.00	$240.00	$45.00	$49,602.90
Total	$22.47	$48,723.94	$5,271.78	$1,113.62	$377.33	$93.92	$55,580.59
Disbursements:							
Annual withdrawal authorized in by-laws			$1,477.34				$ 1,477.34
Gold and bronze replicas of Lamme Medal and certificate					$229.30		229.30
Purchase of securities		$48,641.88					48,641.88
All other disbursements				$ 89.43		$71.69	161.12
Total Disbursements		$48,641.88	$1,477.34	$ 89.43	$229.30	$71.69	$50,509.64
Cash on Deposit, April 30 ,1938, With East River Savings Bank and The National City Bank of New York	$22.47	$ 82.06	$3,794.44	$1,024.19	$148.03	$22.23	$ 5,070.95

Five Districts Announce Prize Awards for Papers

District prizes for AIEE papers as announced by five Districts to date include six awards of $25 each, together with appropriate certificates, for initial and Branch papers, and one certificate for best paper. Other District awards will be announced later, as the information becomes available. The awards are for papers presented during 1937, except for Branch papers which may be included in the period from January 1, 1937, to June 30, 1938. Henceforth, according to the revised rules adopted early in 1937, Branch paper prizes will be awarded on the basis of the academic year from July 1 to June 30.

DISTRICT 1

Prize for initial paper was awarded to B. R. Prentice (A'35) for his paper "Fundamental Concepts of Synchronous Machine Reactances," presented at a meeting of the Pittsfield Section, March 30, 1937.

Prize for Branch paper was awarded to Abner Crumb for his paper "Power-Circuit Filters for A-C Generators," presented at the North Eastern District meeting, Buffalo, N. Y., May 7, 1937.

DISTRICT 2

Prize for best paper and prize for initial paper were awarded to F. I. Morgan (A'31) for his paper "An Electrical Governor," presented at a meeting of the Baltimore Section, May 17, 1937.

DISTRICT 6

Prize for Branch paper was awarded to J. L. C. Lof for his paper "The Efficiency of Small Electric Motors," presented at the AIEE Branch convention, North Central District, University of Nebraska, Lincoln, April 22, 1938.

DISTRICT 8

Prize for best paper was awarded to H. H. Skilling (A'28, M'34) and P. deK. Dykes for their paper "Distortion of Traveling Waves by Corona," presented at the Pacific Coast convention, Spokane, Wash., September 1, 1937.

Prize for initial paper was awarded to W. T. Thomson (A'37) for his paper "Resonant Nonlinear Control Circuits," presented at a meeting of the University of California Branch, April 23, 1937. This paper was presented also at the AIEE winter convention, New York, N. Y., January 24–28, 1938.

DISTRICT 10

Prize for best paper and prize for initial paper were awarded to E. O. Lunn (A'32) for his paper "Induction Motors Under Unbalanced Conditions," presented at a meeting of the Vancouver Section, October 4, 1937.

Future Meetings of Other Societies

American Gas Association. October 10–14, Atlantic City, N. J.

American Society of Civil Engineers. Annual convention, July 20–22, Salt Lake City, Utah.

American Society of Mechanical Engineers. Fall meeting, October 5–7, Providence, R. I.

Fuels division meeting, October 13–15, Chicago, Ill.

Illuminating Engineering Society. Annual convention, August 29–September 1, Minneapolis, Minn.

International Congress of Applied Mechanics. September 12–16, Cambridge, Mass.

National Electrical Contractors Association, September 12–15, Detroit, Mich.

National Electrical Manufacturers Association. October 24–28, Palmer House, Chicago, Ill.

National Safety Council. October 10–14, Stevens Hotel, Chicago, Ill.

Society of Automotive Engineers. Sectional regional tractor meeting, September 8–9, Minneapolis, Minn.

National regional fuels and lubricants meeting, October 6–7, Tulsa, Okla.

National aircraft production meeting, October 13–15, Los Angeles, Calif.

Executive Committee of Pacific District Meets

A meeting of the executive committee of the AIEE Pacific District was held at Los Angeles, Calif., May 10, 1938. Those who attended were:

J. P. Jollyman, vice-president, Pacific District
W. F. Grimes, chairman, Los Angeles Section
M. A. Sawyer, secretary, Los Angeles Section
R. O. Brosemer, chairman, San Francisco Section
C. A. Andrews, secretary, San Francisco Section
H. H. Skilling, chairman, District committee on student activities
A. M. Bohnert, secretary, Pacific District

Vice-President Jollyman presided. One of the principal topics discussed was the Institute's forthcoming Pacific Coast convention to be held at Portland, Ore., August 9–12. (Details of the convention may be found elsewhere in this issue.)

The matter of obtaining a traveling speaker to address the various Sections and Branches in the District during the 1938–39 season was referred to the District coordinating committee. The plan of having a traveling speaker was started three years ago, and has resulted in talks by several prominent speakers. The committee also considered several papers of possible interest to the Sections.

Other subjects discussed included the combined summer and Pacific Coast convention to be held at San Francisco, Calif., in 1939, and the proposed California law for licensing engineers.

Additions to Section and Branch Report

F. E. Johnson, Jr., secretary of the AIEE New Orleans Section, has called attention to the fact that the meeting held December 10, 1937, by that Section was a joint Section-Branch meeting and was addressed by students from the Tulane University Branch. This will add one entry to table VII of the "Section and Branch Activities Annual Report for 1937–38" (*EE June '38, p. 263–5*). There were two addresses by students, and the meeting was attended by 90 members and guests. With these added items, the totals at the bottom of the table for all meetings of this type held during the year ending April 30, 1938, will be: 18 Sections, 36 Branches, 67 student talks, and a total attendance of 1,897.

ECPD to Review Engineering Education

Supported by a grant of $10,000 from the Carnegie Foundation for the Advancement of Teaching, the Engineers' Council for Professional Development has arranged for the preparation and publication of a "Report on Engineering Education in 1937" to review and summarize the status of engineering education in that year. This will be based on the great amount of information gathered by the ECPD committee on engineering schools in its investigation for purposes of accrediting engineering curricula in degree-granting institutions of the United States. The work will be in charge of D. C. Jackson (A'87, F'12, past-president) emeritus professor of electrical engineering at Massachusetts Institute of Technology, Cambridge, and formerly president of the Society for the Promotion of Engineering Education. Doctor Jackson has been a member of ECPD and has taken an active part in the study of engineering schools.

The information that will form the basis of the report has been gathered from questionnaires, published material, and the confidential reports of committees that have inspected engineering schools during the past three years. The committee membership is representative of the seven national engineering groups which combine to form ECPD: American Society of Civil Engineers, The American Society of Mechanical Engineers, American Institute of Chemical Engineers, American Institute of Mining and Metallurgical Engineers, AIEE, Society for the Promotion of Engineering Education, and National Council of State Boards of Engineering Examiners.

It is expected that the report will be ready for publication within a year, and copies will be distributed to important engineering libraries and school and society officials.

New York City District Holds Student Convention

On April 28, 1938, a total of 225 students from engineering colleges of metropolitan New York visited the Newark (N. J.) College of Engineering, which was host to the 12th annual AIEE New York City District student convention. Student Branches at the following institutions participated:

Rutgers University, New Brunswick, N. J.
College of the City of New York
Columbia University, New York, N. Y.
Polytechnic Institute of Brooklyn, Brooklyn, N. Y.
Pratt Institute, Brooklyn, N. Y.
New York University, New York, N. Y.
Cooper Union, New York, N. Y.
Stevens Institute of Technology, Hoboken, N. J.
Newark College of Engineering.

Following registration and an inspection of the college laboratories, the visiting groups were conducted to the auditorium of the Public Service Electric and Gas Company, where the technical session was held. The session was opened formally by Convention Chairman Mildred Preen, Newark College of Engineering, who introduced J. W. Johnson, also of the Newark

College, as chairman of the morning session. A. R. Cullimore, president of the college, extended a welcome to the visiting students. J. T. Barron (A'07, F'27) vice-president in charge of electric operation, Public Service Electric and Gas Company, extended greetings to the gathering on behalf of his company.

Papers presented at the technical session were as follows:

1. A New Amplifier, **S. R. Rich,** College of the City of New York.

2. A High-Speed Electronic Circuit Breaker, **Henry Jasik,** Newark College of Engineering.

3. Synchronous Operation of Polyphase Machines With A-C Field Excitation, **Milton Treuhaft and J. R. Bejarano,** Columbia University.

4. A Rate-of-Rise Voltmeter to Be Used in Insulating Tests, **J. P. Messana,** Polytechnic Institute of Brooklyn.

5. Circuits and Testing of the PCC Car, **W. R. Lacy,** Pratt Institute.

Adjournment of the technical session was followed by a luncheon, after which D. C. Luce (A'36, M'36) general superintendent of generation of the Public Service Company, described briefly his company's Essex generating station. At 8 p.m. dinner was served in Duffield Hall of the Newark Athletic Club, following which A. F. Dixon (A'14, F'26) chairman of the AIEE New York Section, spoke on the purpose of Student Branches, and urged that students take an interest in Institute affairs after graduation. H. H. Henline (A'19, M'26) national secretary of the Institute, addressed the gathering on Institute activities of the Student Branches.

For papers presented at the morning technical session, Henry Jasik was awarded the first prize of $25, and J. P. Messana was awarded the second prize of $10. The judges were J. H. Pilkington (A'26, M'34) Consolidated Edison Company of New York, Inc., *chairman;* A. G. Oehler (A'18, F'26) editor of *Railway Electrical Engineer;* and R. W. King (M'35) Bell Telephone Laboratories.

The main speaker of the evening, J. L. O'Toole, a vice-president of the Public Service Company, spoke on the organization of that company. Other guests of the convention included J. F. Fairman (A'20, F'35) secretary of the AIEE New York Section, and Professor H. N. Walker (A'27, M'34) of New York University, District chairman of the counselors.

Current Items From American Engineering Council

"Management Is on the Spot"

Under this provocative heading the commerce and industry committee of the Seventh International Management Congress calls attention to the responsibilities of management to review at a great international gathering such problems as "Management's Responsibilities to Society," "The Continuance of Free Enterprise," "Common Ground for Labor and Management," "Labor's Aims and Responsibilities," "Management's Aims and Responsibilities," and "The Public's Concern in Industrial Harmony" (*EE, Nov. '37, p. 1409*).

This Seventh International Management Congress will be held in Washington, September 19–23, 1938, with headquarters at the United States Chamber of Commerce. American Engineering Council by action of the executive committee has accepted the invitation to become one of the sponsoring organizations of this international meeting.

The first Congress was held in Czechoslovakia in 1924 at the call of the government of that newly established nation. The Seventh Congress, the first to be held in the United States, has the approval of the Departments of State and Commerce. Secretary Hull will open the Congress. Secretary Roper will close it. Official invitations to the 16 participating nations have been transmitted by the Department of State through diplomatic channels. It is expected that some 300 delegates from abroad will meet with representatives of management in the United States to discuss together the responsibilities of management and the detailed consideration of technical phases of management in the fields of administration, production, distribution, personnel, agriculture, and the home.

Spring Meeting of AEC Executive Committee

The spring meeting of the AEC executive committee was held in Philadelphia, Pa., on the morning of May 13, preceding the first forum (*EE, June '38, p. 268*). The committee discussed and acted upon a number of public questions and projects. It was voted to record by resolution the approval of the appointment of a special Congressional committee to conduct a fact-finding investigation of the TVA.

It was voted to empower the president of Council to appoint a special committee representing the profession as a whole to co-operate with the staff of the Army and Navy on questions of national defense. This proposal was in accordance with the recommendation voted by the Assembly at the January 1938, meeting.

Favorable consideration was given to a proposal to sponsor a special inquiry into the status of young engineers, under the general direction of the AEC engineering and allied technical societies committee on engineers' economic status, of which Professor J. S. Dodds is chairman, the work to be conducted by the Personnel Research Federation with funds supplied by The Engineering Foundation.

A factual study of the relation of patents to monopoly, proposed by Chairman R. S. McBride of the AEC patents committee was approved, provided the budget for the purpose could be obtained from sources outside of present member organizations.

The executive secretary announced the election of the Engineers Club of Memphis, Tenn., and the Structural Engineers Association of California as members of AEC, bringing the total members of Council up to 52, the largest in its history.

After reviewing many comments of approval on the new form of the *Bulletin*, the executive committee instructed the executive secretary to inquire into the cost of printing the *Bulletin* in quantity so it might be made available to state and local societies for redistribution by them to their members. General approval was expressed of the appearance and content of the *Bulletin*.

The executive committee received many expressions of approval of the proposed series of public forums to be conducted by Council. Consideration was given to several suggestions for extending and developing the forum idea. A number of local organizations has expressed interest in developing the public forums and it was the consensus of opinion of the executive committee that as soon as Council had had more experience in developing the series of major forums it could perform a useful service by the preparation of a handbook on "how to run a forum" for the use of local committees and chairmen. Plans also were discussed for finding ways and means of putting the results of the series of forums in printed form. The public affairs committee, under whose auspices the forums are being directed, will be particularly glad to receive suggestions and subjects for future forums.

Rural Electrification Loans

H. J. Resolution. 679 amends the Rural Electrification Administration Statute and makes $100,000,000 additional available for loans to rural electrical co-operatives through June 30, 1939. It also provides $1,000,000 for additional salaries and expenses of the REA. This Act does not include any new restrictions or regulations except "that materials acquired for rural electrification uses shall be of domestic origin if possible." Otherwise, the basis for loans, construction requirements, and general operating conditions are the same as those now in use.

An interesting implication regarding the expansion of rural electrification is found in title I, section I, item *d* of the Emergency Relief Appropriation Act of 1938 which reads: "construction of—electric transmission and distribution lines or systems to serve persons in rural areas, including projects sponsored by and for the benefit of nonprofit and co-operative associations." Under this authority, it seems entirely possible for the Works Progress Administration to build rural electrification and turn it over to sponsoring co-operative rural electric associations without obligation beyond the usual sponsors' contribution.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or reject them entirely.

ALL letters submitted for consideration should be the original typewritten copy, double spaced. Any illustrations submitted should be in duplicate, one copy, to be an inked drawing but without lettering, and other to be lettered. Captions should be furnished for all illustrations.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

Graphical Representation of the a-Operator

To the Editor:

The accompanying diagram (figure 1) is a graphical representation of the properties of the a operator which is so widely used for analyzing fault conditions in power networks by the method of symmetrical components. From this diagram the various values of the functions of the a operator are easily obtained and the reason for the particular values readily discerned.

Of interest is the fact that the magnitudes of the functions are either unity or $\sqrt{3}$, as is indicated by the two concentric locus circles. Of further interest is the fact that the functions of the a operator provide a series of operators which will provide phase shifts in 30-degree steps.

A similar diagram can be constructed showing combinations of the operators j and i which will give rotations in 45-degree steps.

Very truly yours,

S. FISHMAN (A'28, M'34)

(Assistant Professor in Electrical Engineering, Newark College of Engineering, Newark, N. J.)

AIEE Publications

To the Editor:

I have been a member of the Institute for 20 years and a casual reader of the JOURNAL and its successor ELECTRICAL ENGINEERING during that time; and I have been most pleased with the change in contents and arrangement that has taken place during the past few years. It is true that the Institute is a professional society, and that the monthly publication should be devoted primarily to the details of electrical research and development. But for every designing or research engineer in the membership there are probably 100 practicing engineers of one kind or another—sales engineers, plant engineers, and management engineers. The more popular and simpler written articles prove especially interesting to this latter group; and very helpful also.

I believe that ELECTRICAL ENGINEERING is now a magazine that is proving useful and stimulating to all of us.

Very truly yours,

N. S. DICKINSON (A'15, M'19)

(Chief Engineer, Motor Sales and Engineering Company, Inc., Newark, N. J.)

Chance and Choice in Engineering

To the Editor:

"Chance and Choice in Engineering," a miniature monograph prepared by Chairman R. L. Sackett of the ECPD committee on selection and guidance, so concisely and effectively presents a matter of interest and importance to the whole engineering profession that I take the liberty of quoting it herewith in full:

It is the business of the engineer to eliminate chance from his work so far as the applications of science will permit. At the same time, boys are taking a chance by choosing an engineering college course without knowing all the facts necessary to sound judgment. Schools, colleges, and the engineering profession should be concerned with reducing the chance of failure and contributing to certainty of success by a co-operative effort to help boys to understand the foundations for a sound choice.

What does engineering education ask of a prospective student?

First: A definite liking for and ability in mathematics, particularly in solving problems.

Second: A scientific curiosity and a deep desire to know *why* and *how* force, electricity, heat, and chemicals act and react as they do.

Third: An interest in drawing, doing things, making things, seeing through them, understanding mechanical, electrical, and other devices, an ability to see in three dimensions or visualization. This latter, valuable aptitude is called by various fancy names, such as "imagination," "creative imagination," seeing "spatial relations," "seeing things with eyes shut."

Fourth: Character, courage, a genuine ambition, supported by dogged determination and many other qualities are either necessary or helpful.

The boy who masters an engineering education has proven that he has capabilities for achievement not only in engineering but in other fields as well, as is attested by the careers of many successful men.

If an engineer is concerned that his profession should raise its standards, then he may give ripe counsel so that able boys with the desirable interests will feel encouraged to apply for admission to an engineering college. Those who are attracted by the spectacular and romantic should understand the nature of the severe discipline ahead of them and make their decision with their eyes open to the realities.

If the engineer is really interested in taking chance out of the choice which boys sometimes take when selecting engineering for a career, the engineer will offer his services to his high school principal. Many local engineering societies are doing a good job. Local sections of the national societies can also help, by organized effort.

I hope that this is in a form that you can print, and also that it may form a basis for discussion or for letters from qualified members in order that this important topic may receive the attention that it merits.

Very truly yours,

CHARLES F. SCOTT (A'92, F'25, HM'29, past president)

(Chairman, Engineers Council for Professional Development, New York, N. Y.)

Cable and Damper Vibration Studies

To the Editor:

In his letter to the editor in the May 1938 issue of ELECTRICAL ENGINEERING Mr. Max Preiswerk states that the mathematical method of calculating the damping action of vibration-free cables as developed in my paper "Cable and Damper Vibration Studies," published in ELECTRICAL ENGINEERING, June 1936, page 600 is incorrect. Mr. Preiswerk states that the results of my calculation do not agree with actual practice and hence the assumptions used to make the problem mathematically

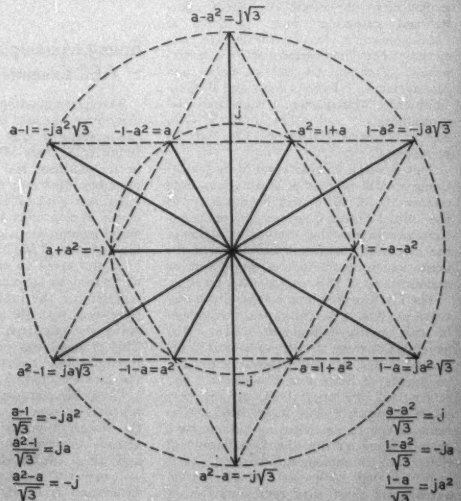


Figure 1. Properties of the a-operator

possible are wrong. Now from the following facts which Mr. Preiswerk mentions in his letter and from the results which were obtained by my theoretical analysis it appears to me that the proposed theory cannot be far in error as I will try to demonstrate by the following:

1. Mr. Preiswerk states in his letter that his vibration-free cables do not vibrate, but that only a slight clicking can be heard. The fact that a slight clicking can be heard appears to me to be inconsistent with the view that the cables never vibrate and seems to be more in accord with the possibility that vibrations tend to get started and are rapidly damped by the energy absorption due to the reaction of the two cables on each other. This appears to be consistent with equation 28 in my paper. This equation shows that any oscillatory disturbance undergoes most rapid attenuation because of the reaction between the two systems.

2. The remark that the amplitudes of traveling waves rapidly diminish as they progress along the conductor is verified by my equations 24, 25, 26, and 27. From these equations it is seen that the damping action due to the reaction between the two systems produces most rapid attenuation of any traveling wave that might be initiated by an external disturbance. This is in perfect agreement with Mr. Preiswerk's observation.

3. Mr. Preiswerk states that in the vibration-free cable the hollow cable and the core cable have such tensions that they try to take different catenary curves. He states that the lifting off and falling back of the hollow cable from the inner core results in damping. The exact mechanism of damping is not very clear from this statement. If a mass is lifted up it acquires more potential energy and this energy will again be transformed into kinetic energy of motion when the mass falls back. Without doubt the slight shock action of the cable, which according to Mr. Preiswerk is not destructive, must be the energy-absorbing mechanism. This effect I have tried to take into account in the equations of motion by a term involving damping proportional to the difference in the velocities of the outer and inner cables. It is true that this may not represent the actual situation exactly but in view of the foregoing two points, it must be at least qualitatively correct.

4. Mr. Preiswerk objects to the method of analysis in which an initial vibration is assumed and the subsequent behavior of the system is studied. If the law of force giving the reaction of the Kaman vortices on the conductor were known, it would be possible to fix the problem to take into account the boundary conditions that the conductor be at rest initially and then to study the effect of the force due to the eddy formation. This mode of attack has interesting possibilities and should bring out some valuable information However, the behavior of the free system showing the manner in which existing disturbances die out gives a qualitative view of the phenomenon.

It is well to mention that Mr. Preiswerk states that his vibration-free cables have now been in practical use for a period of about two years, and are no longer merely a theoretical proposition. It must be realized that the paper in question was written over two years ago and at that time the vibrationless cable was, to the best of my knowledge, still in the experimental stage. A great deal of credit must be given Mr. Preiswerk for the difficult development of his new cable.

Very truly yours,

LOUIS A. PIPES (A'37)

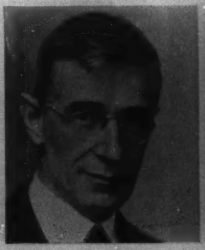
(Research Associate, University of Wisconsin, Madison)

Personal Items

VANNEVAR BUSH (A'15, F'24) has been elected president of the Carnegie Institution of Washington. Doctor Bush is expected to continue his duties as vice-president of Massachusetts Institute of Technology until January 1939. Doctor Bush was born at Everett, Mass., March 11, 1890. In 1913 he was graduated from Tufts College, and in 1916 was awarded the degree of doctor of engineering from Massachusetts Institute of Technology and Harvard University. In 1932 he received the honorary degree of doctor of science from Tufts College, and he is now a member of the board of trustees of that college. Following graduation from Tufts College he entered the testing department of the General Electric Company, Schenectady, N. Y., and during the next year was an instructor in mathematics at Tufts College. In 1915 he became engaged in graduate study at MIT, and in the following year returned to Tufts as assistant professor of electrical engineering. During 1917–18, Doctor Bush carried on research work in submarine detection for the United States Navy; then until 1923 was associate professor of electric power transmission at MIT. From 1917 until 1922 he was also consulting engineer for the American Radio and Research Corporation. In 1923 he was appointed professor of electric power transmission, holding that title until appointed to the position of vice-president and dean of engineering of MIT in 1932. For achievements in electrical engineering he has received the Levy Medal of the Franklin Institute (1928), and he received the AIEE Lamme Medal for 1935. Doctor Bush is a member of the Lamme Medal committee and during the year just ending has been a member of the committees on co-ordination of Institute activities, and Edison Medal; he is also representative on the National Research Council, division of engineering and industrial research. He has served on many other technical and general committees of the Institute. Doctor Bush is a Fellow of the American Academy of Arts and Sciences and American Physical Society, and a member of the Society for the Promotion of Engineering Education, National Academy of Sciences, Phi Beta Kappa, Sigma Xi, and Tau Beta Pi.

C. L. DAWES (A'12, F'35) co-author of the paper "Electrical Characteristics of Suspension-Insulator Units," with Reuben Reiter (A'36) has received the 1937 AIEE national prize award for best paper in theory and research. He is associate professor of electrical engineering at Harvard University, Cambridge, Mass., and a vice-president-elect of the Institute. A biographical sketch of Professor Dawes appeared on page 139 of the March 1938 issue of ELECTRICAL ENGINEERING. In that item Professor Dawes was incorrectly named as chairman of the AIEE Boston Section during the 1937–38 term; in fact he was chairman of that Section during 1936–37.

C. C. CHESNEY (A'94, M'99, F'13) has been elected an honorary member of the Institute. Mr. Chesney was born at Selingsgrove, Pa., October 28, 1863, and was graduated from the Pennsylvania State College in 1885 with the degree of bachelor of science. During the three years following his graduation he taught mathematics and chemistry at Pennsylvania State College and the Doylestown Seminary. In 1888 he joined William Stanley's laboratory staff at Great Barrington, Mass., and in the following year entered the services of the United States Electric Lighting Company, Newark, N. J. In 1890 Mr. Chesney moved to Pittsfield Mass., and became a member of the Stanley



VANNEVAR BUSH

C. L. DAWES

C. C. CHESNEY

Laboratory Company. Three years later he became one of the incorporators of the Stanley Electric Manufacturing Company in the capacity of vice-president and chief engineer. When the Stanley Electric Manufacturing Company was taken over by the General Electric Company in 1907 Mr. Chesney continued as manager and chief engineer of the Pittsfield works. In 1927 he was appointed vice-president of the General Electric Company in charge of manufacturing in all its plants. He retired in 1930 with the title of honorary vice-president. Mr. Chesney has taken an active interest in the affairs of the Institute, serving as manager (1905–08), vice-president (1908–10), and president (1926–27). In 1921 he received the Edison Medal "for early developments in alternating current transmission." He has served as a member of many of the Institute's committees, and as Institute representative on other organizations.

W. B. KOUWENHOVEN (A'06, F'34) has been appointed dean of the school of engineering of The Johns Hopkins University, Baltimore, Md. Doctor Kouwenhoven was born January 13, 1886, at Brooklyn, N. Y. From the Polytechnic Institute of Brooklyn he received the degrees of electrical engineer (1906) and mechanical engineer (1907) and from Karlsruhe Technische Hochschule, Baden, Germany, he received a diploma in engineering in 1913 and the degree of doctor of engineering in 1914. During 1906–07 he was an assistant in physics at the Polytechnic Institute of Brooklyn, and from 1907 until 1910 was an instructor in physics and electrical engineering at the same institution. During 1913–14, he was an instructor in electrical engineering at Washington University, St. Louis, Mo., and in 1914 he joined the faculty of The Johns Hopkins University. Doctor Kouwenhoven was an instructor in electrical engineering from 1914 until 1917, and an associate in electrical engineering from 1917 until 1919. After a leave of absence in 1919, he was appointed associate professor in electrical engineering and held that position until 1930, when he was appointed professor of electrical engineering and assistant dean of the school of engineering. Doctor Kouwenhoven is a director of the Institute, a member of the committees on instruments and measurements, technical program, award of Institute prizes, safety, and electrochemistry and electrometallurgy, and is chairman of the committee on research. From 1931 until 1933, he was a vice-president, and in the past has been member or chairman of several other committees.

J. T. LUSIGNAN, JR. (A'27, M'34) has been appointed executive engineer of the Ohio Brass Company, Mansfield, Ohio. Formerly engineering assistant to the vice-president, Mr. Lusignan now will supervise all engineering activities of the Ohio Brass organization. Born in 1902, at Stockton, Calif., he attended the United States Naval Academy and was graduated from Massachusetts Institute of Technology with the degrees of bachelor of science (1924) and master of science (1925). Later he enrolled in graduate school of Stanford University and received there the degree of doctor of philosophy in electrical engineering in 1928. During 1925–26 he was a research assistant in the high-voltage laboratories of the General Electric Company, Pittsfield, Mass., and following his graduation from Stanford University he returned to that company and remained until 1930. In that year Mr. Lusignan became transmission engineer for the Ohio Brass Company, later becoming chief electrical engineer and engineering assistant to the vice-president. He has been a member of the Institute's committee on power transmission and distribution since 1936, and is active in committee work of the National Electrical Manufacturers Association.

J. B. WHITEHEAD (A'00, F'12) has been appointed director of the school of engineering of The Johns Hopkins University, Baltimore, Md. He has been dean of the school of engineering since 1925. Doctor Whitehead, who was born at Norfolk, Va., August 18, 1872, studied at The Johns Hopkins University, from which he received the degrees of electrical engineer (1893), bachelor of arts (1898), and doctor of philosophy (1902). He was employed first by the Westinghouse Electric and Manufacturing Company, and was associated briefly with the Niagara Falls Power Company and the Pittsburgh Reduction Company. In 1898, he returned to the university as an instructor in electrical engineering, and became associate professor of applied electricity in 1905. He became professor in 1919. Besides having been a manager of the Institute (1924–28) and president (1933–34), Doctor Whitehead has served as chairman or member of many of the Institute's committees, and at present is a member of the committees on Institute activities and the code of principles of professional conduct.

L. N. MCCLELLAN (A'14, M'26) has received honorable mention in the 1937 AIEE national prize awards for best paper in engineering practice with co-authors A. J. A. Peterson (A'16, M'30) and C. P. Garman (A'23, M'26) for the paper "Switchboards For Boulder Power Plant." Mr. McClellan was born at Middletown, Ohio, in 1888, and received the degree of bachelor of science in electrical engineering in 1911 at the University of Southern California. He was then employed by the United States Reclamation Service at Phoenix, Ariz., on the Salt River project as electrical assistant. After serving in various intermediate positions he became engineer in responsible charge of construction and operation of the power system in 1915. During 1917–18 he served as a lieutenant in the United States Army Corps of Engineers, upon his return becoming electrical engineer in the office of the chief engineer of the Reclamation Service at Denver, Colo. Mr. McClellan was employed by the Southern California Edison Company as engineer in the transmission department during 1923–24. Since 1924 he he has been chief electrical engineer for the Bureau of Reclamation at Denver. From 1933 until 1936 Mr. McClellan was a member of the AIEE committee on power transmission and distribution. At present he is a vice-president of the Institute and a member of the committees on automatic stations and applications to mining work.

A. L. COOK (A'02, M'13) has been appointed acting director of the school of science and technology of Pratt Institute, Brooklyn, N. Y. For 25 years Mr. Cook has been head of the department of electrical engineering of that school. Born at Worcester, Mass., in 1878, he was graduated from Worcester Polytechnic Institute with the degree of bachelor of science in electrical engineering in 1901. Following his graduation in 1901, he enrolled in the graduate school at Worcester Polytechnic Institute, at the same time serving as an instructor in electrical engineering, and re-

J. T. LUSIGNAN, JR.

J. B. WHITEHEAD

W. B. KOUWENHOVEN

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A. L. COOK

E. L. MORELAND

W. S. GIFFORD

H. R. REED

D. W. ATWATER

ceived the degree of master of science in 1903. From 1907 until 1913 he was an electric power engineer for the consulting engineering firm of Westinghouse, Church, Kerr, and Company, New York, N. Y., and except for that period he has been associated with Pratt Institute continuously since 1903. From 1903 until 1907 Professor Cook was head of the electrical laboratories; became head of the department of industrial electrical engineering in 1913; and has acted as course supervisor in electrical engineering since 1919. Mr. Cook is the author of several textbooks on electrical subjects, and is a member of the Society for the Promotion of Engineering Education.

D. W. ATWATER (A'34) has been elected president of the Illuminating Engineering Society for the year beginning October 1, 1938. Mr. Atwater is manager of commercial engineering of the Westinghouse Electric and Manufacturing Company's lamp division, Bloomfield, N. J. Mr. Atwater was born August 14, 1894, at Newark, N. J., and was graduated from Stevens Institute of Technology with the degree of mechanical engineer in 1916. Following two years' service with the United States Army during the World War, he became a specification engineer for the Western Electric Company, New York, N. Y., in 1919. In the following year Mr. Atwater became affiliated with the lamp division of the Westinghouse Company. In 1933 he became assistant manager of the commercial engineering department, and was promoted to the position of manager in the following year. Long active in the Illuminating Engineering Society, Mr. Atwater was for three years general secretary of the Society, and at various times has been member or chairman of several of its committees. For two years he was chairman of the illuminating group of the AIEE New York Section, and since 1935 has been a member of the Institute's committee on production and application of light.

W. S. GIFFORD (A'16) recently received the gold medal of the National Institute of Social Sciences "in recognition of his services rendered as director of the Council of National Defence; President of the Charity Organization Society of New York; Trustee of [The] Johns Hopkins University, General Education Board, Carnegie Institute of Washington; director of the President's Organization on Unemployment Relief; president of the American Telephone and Telegraph Company, the greatest non-governmental organized service in the United States; and as trustee of numerous educational and scientific foundations." A native (1885) of Salem, Mass., Mr. Gifford was graduated from Harvard University in 1905 with the degree of bachelor of arts. He received the degree of doctor of law from Williams College in 1928 and from Colgate University in 1929, and the degree of doctor of science from Oberlin College in 1929. Following his graduation from Harvard, Mr. Gifford became assistant secretary and treasurer of the Western Electric Company, Chicago, later becoming chief statistician of that company in 1911. He became vice-president of the Western Electric Company in 1919. He has been president of the American Telephone and Telegraph Company since 1925, and a director of several other organizations. Mr. Gifford has been particularly active in civic and governmental activities. He is a member of the American Philosophical Society and the American Association for the Advancement of Science.

E. L. MORELAND (A'11, F'21) has been appointed dean of engineering of the Massachusetts Institute of Technology, Cambridge. Dean Moreland was born at Lexington, Va., in 1885, and received the degrees of bachelor of arts (1905) and master of science (1908) from The Johns Hopkins University and Massachusetts Institute of Technology, respectively. Upon his graduation in 1908 he entered the engineering firm of D. C. and William B. Jackson, which in 1919 became the firm of Jackson and Moreland. During the World War Dean Moreland served as captain and later as major of engineers in the United States Army, and after the War was appointed technical executive of the War Damage Board. He has served since 1935 as head of the department of electrical engineering at MIT. At present Dean Moreland is a member of the Institute's committees on standards and education and is alternate on the electrical standards committee of the American Standards Association and the United States National Committee of the International Electrotechnical Commission. In addition he has served as a member of the Institute's committees on electrical machinery, power generation, transportation, technical program, and Institute policy. He is a fellow of the American Academy of Arts and Sciences and a member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, and Society for the Promotion of Engineering Education, as well as several honorary scientific societies.

H. R. REED (A'28, M'34) co-author of the paper "Induction Motors on Unbalanced Voltages," with R. J. W. Koopman (A'36) has received the 1937 AIEE national prize award for initial paper. Professor Reed was born in 1904 at Minneapolis, Minn., and received the degrees of bachelor of science (1925) and master of science (1927) in electrical engineering at the University of Minnesota and the professional degree of electrical engineering at South Dakota State College (1930). During 1927–29 Professor Reed served as instructor and assistant professor of electrical engineering at South Dakota State College, was appointed to the faculty of the Michigan College of Mining and Technology, Houghton, as assistant professor in 1929, and in 1932 was promoted to associate professorship. He was employed in the engineering department of the Electric Machinery Manufacturing Company, Minneapolis, Minn., for a brief period in 1926; as an electrical tester for the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1929; and as engineer in the United States Army Corps of Engineers in 1930 at Kansas City, Mo. Professor Reed is a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and the Society for the Promotion of Engineering Education.

L. F. ADAMS (A'09, M'26) has been made manager of the newly formed standards department of the General Electric Company, Schenectady, N. Y. In his new capacity Mr. Adams also will act as assistant to vice-president. Born at Milesburg, Pa., in 1885, he was graduated from Pennsylvania State College with the degree of bachelor of science in electrical engineering in 1906, following which he was employed in the testing department of the General Electric Company. One year later he returned to Pennsylvania State College as an instructor, and in 1909 was awarded the degree of electrical engineer. In the same year Mr. Adams returned to the employ of

the General Electric Company at Schenectady, where he has remained in various positions. Since 1929 he has been in the commercial general department of the company. Mr. Adams has been a member of the United States National Committee of the International Electrotechnical Commission, and has been active in the National Electrical Manufacturers Association.

C. C. CARR (A'30) has been made acting head of the department of electrical engineering and acting course supervisor in electrical engineering at Pratt Institute, Brooklyn, N. Y. Mr. Carr was born May 4, 1898 at Newburgh, N. Y., and was graduated from Rensselaer Polytechnic Institute in 1918. In 1919 he became an electrical draftsman for Newburgh Shipyards, Inc.,

C. C. CARR

Newburgh, N. Y., and in the following year was appointed instructor in electrical technology at Pratt Institute and was placed in charge of the electrical laboratory. He is a member of the Society for the Promotion of Engineering Education.

F. C. LANDERS (A'19) has become vice-president and general manager of the Central Ohio Light and Power Company, Findlay. Mr. Landers was born in 1882 at Lockport, N. Y., and attended Belfast (Ireland) Technical Institute. Prior to 1920 he was superintendent of the western division of the Niagara, Lockport, and Ontario Power Company. In 1920 he became associated with the management department of Day and Zimmerman, Inc., and managed one of the properties of that company in Maryland. Later he became vice-president and general manager of the Valdosta Lighting Company and Ware County (Ga.) Light and Power Company, going to Florida in 1926 to become vice-president and general manager of the General Public Utilities Company in Miami and West Palm Beach. In 1929 he resigned his position with the General Public Utilities Company to take charge of the Louisiana Ice and Utilities Company and the Southwest Utilities Company, with properties located in Louisiana, Mississippi, and Texas. He continued in charge of those companies until his recent transfer to the Central Ohio Light and Power Company.

R. J. W. KOOPMAN (A'36) co-author of the paper "Induction Motors on Unbalanced Voltages," with H. R. Reed (A'28, M'34) has received the 1937 AIEE national prize award for initial paper. Professor Koopman was born at St. Louis, Mo., in 1905, and received the degree of bachelor of science in engineering at the University of Missouri in 1928. In 1933 he received the degree of master of science in electrical engineering at Yale University. He was a Gregory Scholar in electrical engineering at the University of Missouri in 1934–35. After graduation in 1928 Mr. Koopman was employed by the General Electric Company, Schenectady, N. Y., where he completed the test course and later worked in the test office on special assignments. Upon leaving the General Electric Company in 1931 he became an instructor in electrical engineering at Yale University. Later he was employed by the Century Electric Company, St. Louis, Mo., in 1934. Before being appointed to his present position as assistant professor of electrical engineering at the University of Kansas, Lawrence, he was instructor in electrical engineering at the Michigan College of Mining and Technology, Houghton. Professor Koopman is author or co-author of several other technical papers and articles. He is a member of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

J. H. HAGENGUTH (A'28) has received honorable mention in the 1937 AIEE national prize award for best paper in theory and research. Mr. Hagenguth, a native (1901) of Greipwald, Germany, was graduated in 1925 as diplomingenieur from the Technische Hochschule, Munich, Germany. Following his graduation he spent a year in conducting a power survey with the Kraftwerke Westsachsen. In 1926 he entered the employ of the General Electric Company, Pittsfield, Mass., in the transformer testing department. From 1927 until 1933 he was engaged in the power transformer engineering department, where he was active in transformer design, cooperated in the development of the shielded transformer and the investigation of transients in transformers. In 1933 Mr. Hagenguth joined the staff of the high-voltage engineering laboratory of the General Electric Company, and at present is in charge of that laboratory. The paper for which he received honorable mention is entitled "Short-Time Spark-Over of Gaps," and was presented at the AIEE 1937 winter convention. Mr. Hagenguth is author or co-author of several other technical papers and articles.

A. C. MOORHAUS (A'32) recently was elected a vice-president of the Cincinnati Gas and Electric Company, Cincinnati, Ohio. Mr. Moorhaus was born October 20, 1887, at Cincinnati. In 1912 he became general manager and secretary of the Scioto Valley Railway and Power Company, holding those positions until 1924, when he became purchasing agent for the Cincinnati Gas and Electric Company. In 1930 he was appointed acting general manager, a position he held until his recent election to the vice-presidency.

HOWARD DINGLE (A'07) recently was elected president of the American Gear Manufacturers Association. Mr. Dingle is president of the Cleveland Worm and Gear Company, Cleveland, Ohio. He was born at Asbury Park, N. J., in 1883, and received the degree of mechanical engineer in electrical engineering at Cornell University in 1905. From 1910 until 1918 he was a district manager for the Crocker-Wheeler Electrical Manufacturing Company. In the latter year he became president and treasurer of the Dingle-Clark Company, remaining in that position for six years. In 1924 he became vice-president and general manager of the Cleveland Worm and Gear Company, and has been president since 1927. He is a member of the Society of Automotive Engineers.

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A. C. MOORHAUS

F. C. LANDERS

R. J. W. KOOPMAN

HOWARD DINGLE

A. P-T. Sah (A'35, M'36) has received honorable mention in the 1937 AIEE national prize award for best paper in theory and research for his paper "Dyadic Algebra Applied to 3-Phase Circuits." Doctor Sah, who formerly was a visiting professor of the electrical engineering faculties of both the Ohio State University and Massachusetts Institute of Technology, was born in 1902 at Foochow, China, and after receiving the degree of bachelor of arts at Stanford University in 1924, enrolled in the electrical engineering school of Worcester Polytechnic Institute, where he received the degrees of electrical engineer (1925) and doctor of science (1927). For one year after his graduation in 1927 he was affiliated with the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pa., following which he became chief engineer of the China Radio Corporation, Tientsin. In 1928 he was appointed assistant professor of electrical engineering and physics at Tsing Hua University, Peiping, and in the following year received his full professorship. In 1936 Doctor Sah returned to the United States as visiting professor of electrical engineering at The Ohio State University and Massachusetts Institute of Technology. In 1937 he returned to China to become president of the National University of Amoy. Since 1935 he has served as a member of the Chinese National Electrotechnical Committee, affiliated with the International Electrotechnical Commission, and is a member of several Chinese scientific societies.

Eugene Peterson (M'26) co-author of the paper "Magnetic Generation of a Group of Harmonics," with J. M. Manley and L. R. Wrathall, has received honorable mention in the 1937 AIEE national prize award for best paper in theory and research. Born in New York, N. Y., in 1894, Mr. Peterson attended Cornell University, and received the degree of electrical engineer at the Polytechnic Institute of Brooklyn in 1917. He then pursued graduate work at Columbia University, receiving the degrees of master of arts in 1923 and doctor of philosophy in 1926. From 1915 until 1917 he was employed by the Electrical Testing Laboratories, New York, and following a two-year period of service in the Signal Corps of the United States Army, he became associated with the Western Electric Company in 1919. Mr. Peterson has been a member of the technical staff of the Bell Telephone Laboratories since 1925, and at present is circuit research engineer, engaged in studies of carrier-communication systems and nonlinear circuits. During 1924–25 he was a lecturer on electric oscillations at the Polytechnic Institute of Brooklyn, and since 1935 has been a lecturer on electronics at Columbia University. Mr. Peterson is a member of the Institute of Radio Engineers and Sigma Xi.

R. D. Evans (A'21, M'26) with co-author A. C. Monteith (A'25) has received honorable mention in the 1937 AIEE national prize award for best paper in engineering practice for the paper "System Recovery Voltage Determination By Analytical and A-C Calculating Board Methods." Mr. Evans was born in 1892 at Springwater, Wis., and received the degree of bachelor of science in electrical engineering at the University of Oklahoma in 1914, following which he entered the employ of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., as a general engineer. He has been affiliated with that company continuously, and recently was made consulting transmission engineer for the company. Mr. Evans has been a member of the Institute's committee on power transmission and distribution since 1924, and at present is chairman of that committee. He was a member of the committee on communications from 1924 until 1934. He has presented several papers before the Institute, principally on transmission-line calculations, power-system stability, and network theory, and is co-author of a textbook on the theory of symmetrical components. In 1929 he was awarded the Triennial Montefiore prize jointly with C. F. Wagner (A'20, M'27) for contributions to the theory of power-system stability.

G. M. L. Sommerman (A'31, M'37) has received honorable mention in the 1937 AIEE national prize awards for best paper in theory and research for his paper "Properties of Saturants for Paper-Insulated Cables." For the same paper he was awarded the Alfred Noble prize for 1937. Doctor Sommerman was born in 1909, at Baltimore, Md., and received the degrees of bachelor of engineering (1929) and doctor of engineering (1933) at The Johns Hopkins University. Following his graduation in 1929 he became a research assistant at that institution, devoting his attention to investigations sponsored by the former National Electric Light Association, and in the following year enrolled in the graduate school of electrical engineering. In 1931 he became an assistant physicist for the Consolidated Gas, Electric Light, and Power Company of Baltimore, and in 1934 joined the research engineering staff of the American Steel and Wire Company, where he has been in charge of fundamental researches on properties of materials for use in high-voltage cables. Doctor Sommerman is a member of the Institute's committees on research and instruments and measurements. He has been an active member of the committee on electrical insulation of the division of engineering and industrial research of the National Research Council. He is a member of several scientific societies.

A. J. A. Peterson (A'16, M'30) with co-authors L. N. McClellan (A'14, M'26) and C. P. Garman (A'23, M'26) has received honorable mention in the 1937 AIEE national prize award for best paper in engineering practice for the paper "Switchboards for Boulder Power Plant." Mr. Peterson was born at Pittsburgh, Pa., in 1892, and was graduated from Carnegie Institute of Technology with the degree of bachelor of science in electrical engineering. Following his graduation he was employed by the Carnegie Steel Company as assistant to the electrical engineer in 1913. In the following year he became a switchboard engineer for the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., where he remained until 1917. During the World War he served in the United States Army, and at the end of the war was employed by the Pennsylvania Railroad Company in 1919. Since 1921 Mr. Peterson has been a switchboard engineer in the switchboard engineering department of the Westinghouse Company.

W. P. Holben (A'20, M'27) has received honorable mention in the 1937 AIEE national prize award for initial paper, for his paper "A Review of Overhead Secondary Distribution." Born at Allentown, Pa., in 1892, Mr. Holben was graduated from Pennsylvania State College with the degree of bachelor of science in 1916, following which he became associated with the Union Switch and Signal Company, Swissvale, Pa. After serving in the United States Army during the World War, he returned briefly to the employ of the Union Switch and Signal Company, and was engaged briefly in railway electrification work, before becoming affiliated with William H. Taylor and Company, Allentown. During 1924–25 Mr. Holben was assistant to the distribution engineer for the Pennsylvania Power and Light Company, and in the latter year joined the engineering staff of the Philadelphia Company, Pittsburgh, Pa., and the Byllesby Engineering and Management Corporation. He is now engaged in the engineering and construction department of the Duquesne Light Company, an affiliated organization, with headquarters at Pittsburgh.

C. P. Garman (A'23, M'26) co-author of the paper "Switchboards for Boulder Power Plant," with L. N. McClellan (A'14, M'26) and A. J. A. Peterson (A'16, M'30) has received honorable mention in the 1937 AIEE national prize award for best paper in engineering practice. Mr. Garman was born in 1888 at Dayton, Ohio, and received his technical education through extension courses of the University of California. After holding several positions for short periods, Mr. Garman became superintendent of the test department of the Dayton Power and Light Company in 1913, remaining there until 1920, when he went to Los Angeles to become junior electrical engineer for the Bureau of Power and Light. For the past eight years he has been assistant engineer in design, and when construction work was started at Boulder Dam he was appointed by the Bureau of Power and Light to co-operate with the government in the design of Boulder Canyon power plant and the preparation and specifications for its machinery and equipment.

I. F. Kinnard (A'21, M'28) co-author of the paper "Development of a Modern Watt-Hour Meter," with H. E. Trekell (A'35) has received honorable mention in the 1937 AIEE national prize award for best paper in engineering practice. Mr. Kinnard was born in Ontario, Canada, in 1891, and received the degree of bachelor of science in electrical engineering from Queen's University. After two years of advanced study at Queen's University and the University

of Glasgow (Scotland), he became a research engineer for the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1919. In 1923 he became electrical engineer at the West Lynn (Mass.) works of the General Electric Company, where he became engaged in research work on permanent magnets, watt-hour meters, and various other electrical instruments. In 1927 he was appointed assistant chief engineer of the West Lynn works, later being assigned to the position of executive engineer.

E. E. Dorting (A'13, M'22) recently was made assistant engineer in the office of the chief engineer of the Interborough Rapid Transit Company, New York, N. Y. A native (1889) of New York, Mr. Dorting attended Stevens Institute of Technology before entering the employ of the Westinghouse Lamp Company, Bloomfield, N. J., as a student engineer in 1908. He remained with that company until 1911, when he became factory engineer for the Heany Lamp Company, Weehawken, N. J. Mr. Dorting became assistant chief tester for the Edison Storage Battery Company, West Orange, N. J., in 1913, but remained there for only one year before becoming affiliated with the Interborough Rapid Transit Company as lighting engineer. He held that position for almost 24 years. Mr. Dorting is a member of the Illuminating Engineering Society and has been active in the committee work of that society.

A. C. Monteith (A'25) with co-author R. D. Evans (A'21, M'26) has received honorable mention in the 1937 AIEE national prize award for best paper in engineering practice for the paper "System Recovery Voltage Determination By Analytical and A-C Calculating Board Methods." Mr. Monteith was born in 1902 at Brucefield, Ont., Canada, and received the degree of bachelor of science from Queen's University. In 1922 he took the student course offered by the Canadian Westinghouse Company, Hamilton, Ont., and following his graduation was selected for the graduate student course and sent to the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. Upon completion of the student course Mr. Monteith was made a general engineer for the company, and he has remained there continuously for more than 14 years.

L. S. Harrison (M'19) has resigned his position as assistant to the president of the International Business Machines Corporation, New York, N. Y., to establish consulting engineering offices in New York. Mr. Harrison will specialize in problems in industrial research, and has become associated with the Technical Research Products Corporation. He was resident agent of the General Electric Company at Trenton, N. J., from 1919 until 1923, when he entered the employ of the International Business Machines Corporation as field engineer, later holding various other positions until 1932. In that year he was placed in charge of research development and engineering. In 1936 Mr. Harrison became assistant to the president and remained in that capacity until his resignation. He has been retained by the corporation on a consulting basis.

H. E. Trekell (A'35) co-author of the paper "Development of a Modern Watt-Hour Meter," with I. F. Kinnard (A'21, M'28) has received honorable mention in the 1937 AIEE national prize award for best paper in engineering practice. Mr. Trekell is a native (1910) of Wellington, Kans., and an electrical engineering graduate of Kansas State University in the class of 1931. In 1932 he was employed by the General Electric Company on the test course at the Schenectady (N. Y.) works, and upon completion of the test course was assigned to the company's advanced course in engineering. In 1934 Mr. Trekell was transferred to the engineering department of the West Lynn (Mass.) works of the General Electric Company, where he became engaged in work on watt-hour meters.

H. C. Gardett (A'07, M'19) recently was advanced to the position of assistant chief electrical engineer and assistant general manager of the Bureau of Power and Light of the City of Los Angeles, Calif. Mr. Gardett, previously design and construction engineer, was born in California in 1878, and is an electrical-engineering graduate of the University of California in the class of 1904. In 1905 he became a meter inspector for the Pacific Electric Railway Company, and two years later became associated with the consulting engineering firm of E. F. Scattergood (A'08, F'13). Mr. Gardett became associated with the Bureau of Power and Light of the City of Los Angeles in 1912 as an assistant electrical engineer. He was placed in charge of the design and construction department in 1917.

J. A. Cranston (A'08) recently retired from active service as commercial vice-president of the General Electric Company, San Francisco, Calif. Mr. Cranston was born April 7, 1862 at Bayfield, Ont., Canada, and first became identified with the electrical industry in 1889, when he joined the Thomson-Houston Company at St. Paul, Minn. Shortly after the Thomson-Houston Company became a part of the General Electric Company in 1892, Mr. Cranston became manager of the Northwest territory of the new company, with headquarters at Portland, Ore. In 1923 he went from Portland to San Francisco to become Pacific Coast manager, and in the same year was elected a commercial vice-president of the General Electric Company.

B. R. Prentice (A'35) has received honorable mention in the 1937 AIEE national prize award for initial paper for his paper "Fundamental Concepts of Synchronous Machine Reactances." A native (1906) of Clifton, Kans., Mr. Prentice received the degree of bachelor of science in electrical engineering at Kansas State College in 1930, following which he was employed by the General Electric Company on its test course. In 1932 he was assigned to the company's advanced course in engineering, and in the following year was made a supervisor of one of the advanced courses. Since 1935 he has been in charge of the company's advanced course in engineering.

Willard Champe (A'25, M'35) has become electrical engineer for the City of Toledo (Ohio) in the division of engineering and construction. Mr. Champe has been employed in the electrical engineering department of the Commonwealth and Southern Corporation, Jackson, Mich., and formerly (1931–36) was an assistant editor on the staff of Electrical Engineering. He is co-author of a paper entitled "System Analysis For Petersen Coil Application," presented at the recent AIEE summer convention at Washington, D. C.

H. L. Doherty (A'98, F'13) recently received the honorary degree of doctor of science from the University of Miami (Fla.). In receiving the degree, Doctor Doherty was cited as "a pioneer in the fight to prevent waste of our resources of natural gas and petroleum." A few months ago Doctor Doherty was awarded the Anthony F. Lucas medal of the American Institute of Mining and Metallurgical Engineers, relative to which a biographical sketch appeared on page 44 of the January 1938 issue of Electrical Engineering.

G. W. Vinal (M'19) received the Gaston Plante Medal of the Société Française des Electriciens at the recent AIEE summer convention in Washington, D. C. A previous item (*EE, Feb. '38, p. 85*) announcing the award of the medal to Doctor Vinal contained two errors. That item incorrectly stated that he received from Wesleyan University the degrees of bachelor of arts in 1909 and bachelor of science in 1936. These degrees should have been given as master of arts and doctor of science, respectively.

Gano Dunn (A'91, F'12) recently received the honorary degree of doctor of science from Columbia University. Doctor Dunn, president of the J. G. White Engineering Corporation, New York, N. Y., was awarded the AIEE Edison Medal for 1937 at the last winter convention, relative to which a biographical sketch appeared on page 44 of the January 1938 issue of Electrical Engineering.

L. B. Bonnett (A'18, M'25) has become assistant engineer of design and planning of the Consolidated Edison Company of New York, Inc., New York, N. Y. Mr. Bonnett became associated with the Brooklyn Edison Company in 1923 as inside plant engineer in the inside plant bureau, electrical engineer's department. He held that position until 1926, when he went to the purchasing department as purchasing agent.

E. H. Lewis (A'25, M'32) recently was elected first vice-president of the Missouri Association of Public Utilities. Mr. Lewis is vice-president of the Union Electric Company of Missouri, Webster Groves, and has been in the service of the Union Electric Company and its affiliates since 1915.

A. E. FRENCH (A'36) recently was appointed head of the department of technical electricity, New York State School of Agriculture, Alfred University, Alfred, N. Y. Mr. French is a native (1910) of Avoca, N. Y. He attended the Rochester (N. Y.) Athenaeum and Mechanics Institute and was graduated from Clarkson College with the degree of bachelor of science in 1934. Since 1935 he has been an assistant electrical engineer for the Eastman Kodak Company, Rochester.

W. J. HOLMAN, JR. (A'30) recently was declared a winner in a national competition for the Alfred P. Sloan Foundation fellowship for a year's graduate study in business administration and economics at Massachusetts Institute of Technology. Since 1933 Mr. Holman has been assistant district manager of the Newburgh district of the Central Hudson Gas and Electric Corporation, and for a time was an instructor in electrical engineering at Yale University.

W. H. HARRISON (A'20, F'21) recently received the honorary degree of doctor of engineering from the Polytechnic Institute of Brooklyn (N. Y.). He is vice-president and chief engineer of the American Telephone and Telegraph Company, New York, N. Y., and president of the Institute during 1937–38. A biographical sketch of Doctor Harrison appeared on page 231 of May 1938 issue of ELECTRICAL ENGINEERING.

H. E. DEARDORFF (A'37) recently was awarded a James H. McGraw prize of the Edison Electric Institute for a paper "The Gathering and Evaluation of Data for Improving 4-Kv Distribution System Operation." Mr. Deardorff is technical engineer for the Dayton Power and Light Company, Dayton, Ohio, and has been employed by that company and its affiliates since 1917.

SIDNEY GOLDSMITH (A'28) has been awarded a James H. McGraw prize of the Edison Electric Institute as co-author of a paper "A New Technique in the Maintenance of Oil Circuit Breakers." Mr. Goldsmith is an operating engineer for the Cincinnati Gas and Electric Company, Cincinnati, Ohio.

H. B. TAYLOR (M'26) recently was elected president of the Navy League of the United States. Mr. Taylor maintains consulting engineering offices at Philadelphia, Pa., and has long been identified with hydraulic engineering and some of the major water power developments in the United States and elsewhere.

F. M. FEIKER (M'34) recently was awarded the honorary degree of doctor of engineering by Worcester Polytechnic Institute. Doctor Feiker received the degree of bachelor of science in electrical engineering at that institution in 1904. At present he is executive secretary of the American Engineering Council, Washington, D. C.

R. W. SORENSEN (A'07, F'13) recently was awarded the honorary degree of doctor of science by the University of Colorado. Doctor Sorensen is professor of electrical engineering at California Institute of Technology, Pasadena. He is a director and past vice-president of the Institute, and has served as a member of several of its committees.

E. F. W. ALEXANDERSON (A'04, F'20) recently was awarded the honorary degree of doctor of philosophy *in absentia* by the Royal University of Upsala, Sweden. Doctor Alexanderson is a consulting engineer for the General Electric Company, Schenectady, N. Y., and has been affiliated with that company since 1902.

C. C. PAYNE (A'29, M'38) recently was appointed deputy electrical engineer in the Municipal Electricity Supply Department, Singapore, Straits Settlement. Mr. Payne has been control engineer for the Central Electricity Board of the Mid-East England area, Leeds, Yorkshire, England.

G. E. HOLLAND (A'34) has become assistant sound engineer for the United States Army Motion Picture Service, St. Louis, Mo. Mr. Holland formerly was junior electrical engineer for the Farm Security Administration, Washington, D. C.

L. P. MORRIS (A'30) has become development engineer for the Crowe Nameplate and Manufacturing Company, Chicago, Ill. Formerly Mr. Morris was radio development engineer for Sparks-Withington Company, Jackson, Mich.

R. S. MEYERS (A'37) now is manager of the American Automatic Alarm Company, Baltimore, Md. Formerly Mr. Meyers was assistant plant engineer for the American District Telegraph Company, New York, N. Y.

J. W. POBST (A'37) recently became affiliated with the Appalachian Electric Power Company, Switchback, W. Va. Mr. Pobst has been a student engineer for the General Electric Company, Schenectady, N. Y.

VINCENT EMANUEL (A'34) now is employed by the Stanolind Oil and Gas Geophysical Laboratory, Tulsa, Okla. Formerly Mr. Emanuel was an observer for the Western Geophysical Company, Los Angeles, Cal.

F. E. LEGGETT (A'32) has become chief draftsman for S. J. Welch, architect, Pensacola, Fla. Formerly Mr. Leggett was draftsman for the State-Wide Highway Planning Survey, Florida State Road Department, Tallahassee.

V. M. CATALDO (A'37) recently was employed by the Porto Rico Reconstruction Administration, Guayama, Porto Rico. Mr. Cataldo formerly was employed by Sears Roebuck and Company, New York, N. Y.

C. R. BOOTHBY (A'29) has become a research engineer for the Electric Auto-Lite Company, Toledo, Ohio. Mr. Boothby previously was employed by the Westinghouse Electric and Manufacturing Company, Springfield, Mass.

J. C. PATTERSON (A'31) has become supervisor of telegraph and signals in the New York division of the Pennsylvania Railroad Company, Jersey City, N. J. He formerly held a similar position at Washington, D. C.

H. R. ANDERSON (A'27, M'36) transmission engineer for the Loup River Public Power District, Columbus, Nebr., recently resigned to join the staff of the Federal Power Commission, Washington, D. C.

B. G. OLVING (A'26) now is employed by The McGraw Electric Company, Elgin, Ill. Mr. Olving has been development engineer for the Safety Car Heating and Lighting Company, New Haven, Conn.

M. O. ZIGLER (A'37) now is employed by the Central New York Power Corporation, Syracuse, N. Y. Formerly Mr. Zigler was an electrical engineer for the Federal Power Commission, Denver, Colo.

F. W. BLISS (A'30) recently was re-elected to serve his third consecutive term as president of the Engineering Societies of New England, Inc., Boston, Mass.

A. R. ROBISON (A'12, M'20) recently resigned as vice-president and general manager of the Central Ohio Light and Power Company, Findlay.

K. E. GORDON (A'30) recently became assistant engineer for the New England Power Service Company, Malden, Mass.

R. L. BERTOLACCI (A'19) has been employed in the valuation department of the Duquesne Light Company, Pittsburgh, Pa.

Obituary

STEPHEN JOSEPH CONNOLLY (A'08) construction engineer for the Western Public Service Company, Scottsbluff, Nebr., died January 29, 1938. Mr. Connolly was born July 21, 1875, at Denver, Colo., and attended Jesuit College (Denver). In 1892 he started his electrical career as an apprentice with the Columbian Electric Company, but remained there for only one year before becoming associated with the West End Street Railroad Company, Denver, where he remained for 6½ years. In 1900 Mr. Connolly left the employ of the West End Street Railroad Company, and after a brief association with two mining companies in Colorado, he was employed by the Northern Coal and Coke Company and placed in charge of the electrical work for several coal mines. Two years later he became associated with the Portland Gold Mining Company, Colorado Springs, Colo., first as chief electrician and later as chief engineer of the mill department and consulting engineer of construction, remaining in the last position until 1923. Mr. Connolly left the employ of the Portland Gold Mining Company in 1923 to become affiliated with the Western Public Service Company at Scottsbluff and served that company continuously for 15 years.

PERCY ARTHUR ROBBINS (A'03) retired mining engineer, Chicago, Ill., died April 23, 1938. Mr. Robbins was born in Chicago, May 23, 1874, and was graduated from

Cornell University with the degree of mechanical engineer in 1894. For two years after his graduation he was employed by the Philadelphia (Pa.) Traction Company, and in 1896 became consulting mechanical and electrical engineer for the DeBeers Consolidated Mines, Kimberley, South Africa. Mr. Robbins became general manager of the McKinley Darragh Mines, Cobalt, Ont., Canada, in 1908, remaining there until 1911. In the latter year he became general manager of the Canadian Mining and Finance Company. Beginning in 1919 he served as managing director of the Hollinger Consolidated Gold Mines, Timmins, Ont. Mr. Robbins held several patents and introduced new methods of gold mining in South Africa and Canada. He was a member of the American Institute of Mining and Metallurgical Engineers, the Institution of Mining and Metallurgy (British), and the Canadian Institute of Mining and Metallurgy.

RICHARD GREEN (A'34) electrical superintendent of the Demerara Electric Company, Ltd., Georgetown, British Guiana, died March 29, 1938. Mr. Green was born February 14, 1885, at Georgetown, and received his technical education through the American School of Correspondence. He first became affiliated with the Demerara Electric Company in 1904 as a storekeeper; four years later he became an apprentice in the meter testing department. In 1910 Mr. Green was appointed foreman of that department, and in the following year was appointed assistant electrical engineer. From 1912 until 1923 he was foreman of the company's street railway cars and in the latter year was appointed electrical superintendent of the company. Five years later Mr. Green was placed in charge of the company's distribution system, and in the following year again became electrical superintendent, a position he held for more than nine years.

LARS RASMUS JORGENSEN (A'05, M'13) consulting hydroelectric engineer, Berkeley, Calif., died May 8, 1938. Mr. Jorgensen was born April 25, 1876 at Faaborg, Denmark, and was graduated from the University of Berlin (Germany) with the degree of electrical engineer. After serving a brief apprenticeship in Germany he came to the United States and was employed by the General Electric Company, Schenectady, N. Y., from 1901 until 1903. In the latter year he went to California, where he worked on the engineering staff of several power companies. In 1907 he became a member of the consulting engineering firm of F. G. Baum and Company, and seven years later established his own firm, the Constant Angle Arch Dam Company of San Francisco. Mr. Jorgensen became well known for his work on arch dams, and was awarded the Norman medal of the American Society of Civil Engineers in 1918.

RAY PHILIP JACKSON (A'06) engineering representative in the patent department of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., died in November 1937, according to word just received at Institute headquarters. Mr. Jackson was born at Walton, Mich., April 11, 1873, and was graduated in electrical engineering from the University of Michigan in 1902. Immediately following his graduation he became associated with the Westinghouse Company, with which he never broke his affiliation. In recent years he was manager of the materials and processes engineering department, for a time was works manager of the company's Emeryville (Calif.) plant, and for the last ten years was advisory engineer in the company's patent department.

GAILEN ELMER MEREDITH (A'19, M'26) foreman of the high-voltage laboratory, Kansas City Power and Light Company, Kansas City, Mo., died April 20, 1938. Mr. Meredith was born at Winchester, Kans., February 15, 1890, and received his formal technical education through correspondence schools and extension courses of the University of Missouri. He became affiliated with the Kansas City Power and Light Company in 1905 and was employed by that company continuously, except for two years' service in the United States Army during the World War. He became superintendent of the engineering research laboratory in 1922.

EARLE T. WALKER, JR. (A'35) inspector for the Underwriters Laboratories, Boston, Mass., died September 22, 1937, according to word just received at Institute headquarters. Mr. Walker was born December 26, 1906 at Providence, R. I., and was graduated from Wentworth Institute (Boston) in 1928. Following his graduation he was employed by D. W. Flint, Inc., where he became engaged in automotive electrical work. He had been associated with the Underwriters Laboratories since 1929.

Membership

Recommended for Transfer

The board of examiners, at its meeting on June 15, 1938, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Cloke, Paul, dean of college of technology, University of Maine, Orono.
Douglas, J. F. H., associate professor of electrical engineering, Marquette University, Milwaukee, Wis.
Evans, H. S., dean, college of engineering, University of Colorado, Boulder.
Sayles, E. V. S., electrical engineer, The Commonwealth and Southern Corporation, Jackson, Mich.
Thompson, J. S., president, Pacific Electrical Manufacturing Corporation, San Francisco, Calif.

5 to Grade of Fellow

To Grade of Member

Diggs, V. A., engineer of plant extensions, The Ohio Bell Telephone Company, Cleveland, Ohio.
Elzi, J. A., engineer, The Commonwealth and Southern Corporation, Jackson, Mich.
Fisher, L. B., research engineer, Bull Dog Electric Products Company, Detroit, Mich.
Fleshler, A. D., assistant electrical engineer, Transit Commission, New York, N. Y.
Gilson, W. J., managing director, Eastern Power Devices, Ltd., Toronto, Ont. Canada.
Heller, J. E., system long lines supervisor, The Pacific Telephone and Telegraph Company, San Francisco, Calif.
Hovey, B. K., instructor in electrical engineering University of Alabama, University, Ala.
Kane, E. K., network transformer development engineer, General Electric Company, Pittsfield, Mass.
Leeds, W. M., electrical engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
McCracken, G. W., chief engineer, Birmingham Electric Company, Birmingham, Ala.
Patterson, A., chief engineer, Southwestern Gas and Electrical Company, Texarkana, Ark.
Schott, R. C., electrical engineer, Sanderson and Porter, New York, N. Y.
Scott, H. H., engineer, General Radio Company, Cambridge, Mass.
Siegfried, V., assistant professor of electrical engineering, Worcester Polytechnic Institute, Worcester, Mass.
Smith, F. V., electrical engineer, Sargent and Lundy, Inc., Chicago, Ill.
Tate, V. E., secretary and patent attorney, Perfex Corporation, Milwaukee, Wis.
Zippler, William N., electrical engineer, Gibbs and Cox, Inc., New York, N. Y.

17 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before July 31, 1938, or September 30, 1938, if the applicant resides outside of the United States or Canada.

United States and Canada

Ambos, C., John E. Fast and Company, Chicago, Ill.
Athens, E. P. (Member), Westinghouse Electric and Manufacturing Company, Miami, Fla.
Austin, W. L. (Member), Light and Power Department, Cushing, Okla.
Bishop, E. R., Canadian Westinghouse Company, Ltd., Hamilton, Ont., Canada.
Dawson, T. J., Standard X-Ray Sales Company, Dallas, Texas.
Day, J. H., I-T-E Circuit Breaker Company, Philadelphia, Pa.
Fairbanks, R. P. (Member), Twentieth Century-Fox Film Corporation, Beverly Hills, Calif.
Pinnell, R. D., Kansas Gas and Electric Company, Wichita, Kans.
Fischle, C. R. (Member), New York Telephone Company, New York, N. Y.
Freedson, M., 488 Blue Hill Avenue, Roxbury, Mass.
Gillies, G. B., Gillies Brothers, Ltd., Braeside, Ont., Canada.
Gray, W. F., Texas Technological College, Lubbock.
Graybill, K. W. (Member), Automatic Electric Company and Associated Electric Laboratories, Inc., Chicago, Ill.
Harrop, J. T., M. A. Shaw, Inc., New York, N. Y.
Hill, S. C. H., Shawinigan Water and Power Company, Victoriaville, Que., Canada.
Hirsh, D. (Fellow), Hatfield Electric Company Inc., Houston, Texas.
Johnson, W. P., Toledo Edison Company, Toledo Ohio.
Jones, L. L., American Can Company, Seattle, Wash.
Kilgour, B. L. Jr. (Member), Cincinnati and Suburban Bell Telephone Company, Cincinnati, Ohio.
Krause, F., 7319 68th Road, Middle Village, N. Y.
Marshall, L. C., University of California, Berkeley, Calif.
McCurley, J. B., Western Electric Company, Baltimore, Md.
Merrill, J. R., Consolidated Edison Company of New York, Inc., Brooklyn, N. Y.
Morgan, S. C., University of British Columbia, Vancouver, B. C., Canada.
Mosele, M. P., Public Service Company of Northern Illinois, Chicago, Ill.
Neil, F. M., Sutton, Steele and Steele, Inc., Dallas, Texas.
Nichols, R. E., Connecticut Power Company, Stamford, Conn.
Onaka, T., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Oppen, W. R., Ford Instrument Company, Inc., Long Island City, N. Y.
Partridge, H. R. (Member), Le Carbone Company, Inc., Boonton, N. J.
Pool, R., Southwestern Light and Power Company, Lawton, Okla.
Reed, D. G., Standard Oil of California, Richmond, Calif.
Schmitt, G. H. Jr., 4616 South Roman Street, New Orleans, La.
Smith, T. H., Cleveland Electric Illuminating Company, Cleveland, Ohio.

Smith, T. L., 79 South Main Street, South Norwalk, Conn.
Specht, W. A., South Dakota State College, Brookings.
Tanner, F. R., Cincinnati Suburban Bell Telephone Company, Cincinnati, Ohio.
Van Blarcom, P. S., Luzerne County Gas and Electric Corporation, Kingston, Pa.

Total, United States and Canada—38

Elsewhere

Anantharaman, V. M., Mettur Dam, Madras, India.
Armstrong, R. C., Melbourne Technical College, Melbourne, Victoria, Australia.
Cox, W. J. (Member), Municipality of Orange, New South Wales, Australia.
Dass, I. L., in care of Thomas Cook and Son, Ltd., London, England.
Dorra, A. Y. (Member), Ministry of Public Works, Cairo, Egypt.
Graham, R. H., Box 72, Gatun, Canal Zone.
Gupta, A. K., Perak River Hydro-Electric Power Company, Ltd., Perak, Federated Malay States.
Ramaswamy, S., Malabar Spinning and Weaving Mills, Ltd., South Malabar, India.
Seshachar, K. V., Tata Iron and Steel Company, Ltd., Jamshedpur, India.
Yamaki, N., Kobe Works, Mitsubishi Denki K. K., Wadamisaki, Kobe, Japan.

Total, elsewhere—10

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the addresses as they now appear on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Ackerson, Cornelius, 2600 West Grand Boulevard, Detroit, Mich.
Alden, Verne E., 1440 Tower Road, Winnetka, Ill.
Elliott, Chester, Box 201, Hobart Mills, Calif.
Finsterwalder, Carl J., 4 Kanes Park, New York N. Y.
Lynch, Earl M., 34–40 West Beaver Street, Jacksonville, Fla.
Markham, Thomas C., Jr., 55 Hanson Place Brooklyn, N.Y.
Neiman, William E., 4060 Elbertson Street, Elmhurst, N. Y.
Nissar, A. R., in care of Thomas Cook and Son, 2 Place de la Madeleine, Paris, France.
Piltch, Abraham, 2224 Eutaw Place, Baltimore, Md.
Powers, Walter H., 603 West Washington, Jackson, Mich.
Willick, Francis L., 2397 East Grand Boulevard, Detroit, Mich.

11 Addresses Wanted

Engineering Literature

New Books in the Societies Library

Among the new books received at the Engineering Society Library, New York recently are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface of the book in question.

PRINCIPLES of ELECTRIC POWER TRANSMISSION. By L. F. Woodruff. Second edition. New York, John Wiley and Sons, 1938. 787 pages, illustrated, 9 by 6 inches, cloth, $3.50. Presents the fundamental scientific principles involved in power transmission and the methods whereby they may be applied to practical engineering problems. Intended for students already familiar with fundamental circuit theory and the operating characteristics of the more important types of a-c machinery, and with the use of complex quantities in calculations. The new edition has been largely rewritten. Improved methods of calculation have been incorporated, mechanical principles treated more fully, and chapters added upon power limits and stability and upon the calculation of fault currents.

THOMAS' REGISTER of AMERICAN MANUFACTURERS, 28th edition, 1938. New York, Thomas Publishing Company, illustrated, 14 by 9 inches, cloth, $10.00 to old subscribers, $15.00 to new subscribers. An annual compilation of American manufacturers. Contains three main sections: A classified directory of products (with index) in which the firms are listed with a capital rating, geographically under each product; an alphabetical list of manufacturers, giving addresses, subsidiaries, branches, etc.; and a trade name index.

VAN NOSTRAND'S SCIENTIFIC ENCYCLOPEDIA. New York, D. Van Nostrand Company, 1938. 1233 pages, illustrated, 11 by 8 inches, leather, $10.00. Aims to provide a reference book covering the basic sciences of physics, chemistry, mineralogy, geology, botany, astronomy, and mathematics; and the applied sciences of engineering, medicine, navigation, and aeronautics. Over ten thousand terms of interest are included, with definitions and fundamental information.

PHOTOELEMENTS and THEIR APPLICATION. By B. Lange, translated by A. St. John. New York, Reinhold Publishing Corporation, 1938. 297 pages, illustrated, 9 by 6 inches, cloth, $5.50. Presents a historical review of the development of photoelements and deals with the theories of semiconductor photoeffects and the properties of photocells. A second section is devoted to the construction and properties of photocells and to their various applications.

ELECTRON and NUCLEAR PHYSICS. By J. B. Hoag. Second edition. New York, D. Van Nostrand Company, 1938, 502 pages, diagrams, charts, tables, 9 by 6 inches, cloth, $4.00. A presentation of the experimental evidence for those concepts which lie in the domain of electron and nuclear physics. The first section concerns the characteristics and emission of electrons; the second, nuclear phenomena including transmutations; and the third, laboratory technique.

Celebration a Lyon du Centenaire de la Mort d' ANDRÉ-MARIE AMPÈRE, 1836–1936. Two volumes, Société des Amis d'André-Marie Ampère, 170 Ave. Jean-Jaurès, Lyon, France, 1936. 523 pages, illustrated, 11 by 9 inches, paper, 100 frs. Contains the proceedings at a commemoration of the centenary of Ampère's death, held at Lyons on March 5 to 8, 1936. The lectures discuss the work of Ampère and also modern developments in electrical engineering.

KINETIC THEORY of GASES. By E. H. Kennard. New York and London, McGraw-Hill Book Company, 1938. 483 pages, diagrams, charts, tables, 9 by 6 inches, cloth, $5.00. Treats the traditional kinetic theory of gases from a modern viewpoint. Suitable for use as a textbook for upper-class students. Contains two chapters of graduate grade on wave mechanics and general statistical mechanics. The electrical and magnetic properties of gases are treated only briefly.

SCIENCE and MUSIC. By Sir J. Jeans. New York, The Macmillan Company, 1937. 258 pages, illustrated, 9 by 6 inches, cloth, $2.75. Considers music from the viewpoint of physics. Gives the physical explanation for various phases of the art, such as sound representation by curves, sounds produced by stretched strings and by air columns, harmony, scales, acoustics, and the physiological interpretation of sound.

HOCHFREQUENZ MESSTECHNIK. (Physik und Technik der Gegenwart, Bd. 3.) By O. Zinke. Leipzig, S. Hirzel, 1938. 223 pages illustrated diagrams, charts, tables, 9 by 6 inches, paper, 15.50 rm. Describes fundamental high-frequency measurements and equipment. Chapters cover the measurement of current, voltage, power, frequency; harmonic vibration; modulation; resistance, capacitance, inductance; conductors and cables.

EINFÜHRUNG in die VIERPOLTHEORIE der ELEKTRISCHEN NACHRICHTENTECHNIK. (Physik und Technik der Gegenwart, volume 2). By R. Feldtkeller. Leipzig, S. Hirzel, 1937. 142 pages, charts, diagrams, tables, 9 by 6 inches, paper, 8.80 rm.; bound, 10 rm. A mathematical treatment of those phases of the quadripole theory which have practical applications in electrical communications.

MAGNETISM. (Physics in Industry). London, Institute of Physics, 1938. 102 pages, illustrated, 10 by 6 inches cloth, 4s. 6d. plus 4d. postage. Contains six lectures by physicists and engineers, delivered in 1937 before the Manchester and district branch of the Institute of Physics, designed to survey present knowledge of the magnetic properties of materials.

VDEF-achberichte, Bd. 9, 1937. Berlin-Charlottenburg, ETZ-Verlag. 242 pages, illustrated, 12 by 8 inches, paper, 12 rm. Contains 59 papers presented at the 39th (1937) meeting of the Verband Deutscher Elektrotechniker. These papers discuss all branches of electrical engineering and give a good review of the present state of the art in Europe.

WAGE INCENTIVE METHODS. By C. W. Lytle. New York, Ronald Press Company, 1938. 468 pages, diagrams, charts, tables, 9 by 6 inches, cloth, $6.00. Aims to assist the selection of the best wage plan for any business, by providing means for comparison of possible methods. Presents all the basic incentive plans in use, with their variations and modifications.

WOOD PRESERVATION. By G. M. Hunt and G. A. Garratt. New York and London, McGraw-Hill Book Company, 1938. 457 pages, illustrated, 9 by 6 inches, cloth, $5.00. Summarizes the essential facts on wood preservation and discusses the agencies of wood deterioration, wood preservatives, preserving processes and equipment, and the properties of treated wood.

TROCKENGLEICHRICHTER. By K. Maier. Munich and Berlin, R. Oldenbourg, 1938. 313 pages, illustrated, 10 by 7 inches, cloth, 18 rm. Describes the general construction and method of operation, the three customary types of dry rectifiers, and the electrical properties of the barrier layer. Devotes some space to the calculations of rectifier operation under different kinds of loads.

GROSSE INGENIEURE, Lebensbeschreibungen aus der Geschichte der Technik. By C. Matschoss. Munich and Berlin, J. F. Lehmanns Verlag, 1937. 334 pages, illustrated, 9 by 6 inches, cloth, 8.40 rm. (6.30 rm. in U.S.). Short biographies of a number of great engineers from all periods of historical time, the information concerning mainly their lives rather than their technical work.

ESSENTIALS of ENGINEERING MATHEMATICS. By J. P. Ballantine. New York, Prentice-Hall, 1938. 502 pages, diagrams, charts, tables, 9 by 6 inches, cloth, $3.75. Considers differential and integral calculus side by side with those parts of analytic geometry, trigonometry, and college algebra that seem logically connected with or dependent on the calculus.

ELECTRICAL MACHINERY. By T. Croft, revised by G. H. Hall. Fourth edition. New York and London, McGraw-Hill Book Company, 1938. 394 pages, illustrated, 8 by 5 inches, cloth, $3.00. The object of this book is to answer the questions of the practical electrical worker and to prepare the beginner to undertake jobs in electrical machinery installation, operation, and maintenance.

KURZSCHLUSSSTRÖME in DREHSTROMNETZEN. By M. Walter. Second edition. Munich and Berlin, R. Oldenbourg, 1938. 167 pages, illustrated, 10 by 6 inches, cloth, 8.80 rm. A treatise on short-circuit currents in three-phase lines. Considers methods of suppression and the protective capacity of switches and fuses.

THE ELECTRICAL ELEMENTS and NEUTRONS AS CLOSED SYSTEMS OF MOVING MATTER, describing a method of their development; nonmathematical. By J. B. Marquis. 8 pages, 8½ by 8¼ inches, 7 illustrations, paper, 30¢. Published by the author (Boonton, N. J.)

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☐ 37-100	Hardaway & Lewis	*Test and Operation of Petersen Coil on 100-Kv System
☐ 37-101	Woodruff	*Transmission-Line Transients in Motion Pictures
☐ 37-112	Sporn and Muller	*The Application and Performance of Carrier-Current Relaying
☐ 37-114	Kierstead	*Some Schemes of Current-Limiting Reactor Applications
☐ 37-115	McEachron & McMorris	*Discharge Currents in Distribution Arresters—Part II
☐ 37-121	Hirshfeld	*The PCC Street Car
☐ 37-122	Fitzgerald	*Results of Operation of PCC Cars in Pittsburgh
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☐ 37-154	Reed	*The Properties of Three-Phase Systems Deduced With Matrices
☐ 37-169	Vernam	*Printing Telegraph Operation of Way Wires
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Papers Presented at North Eastern District Meeting, Lenox, Mass., May 18–20, 1938

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Papers Presented at Summer Convention, Washington, D. C., June 20–24, 1938

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* These papers have been published in the TRANSACTIONS section of ELECTRICAL ENGINEERING.

Transactions

Papers and Discussions Comprising Pages 359–422 of the 1938 Volume

Design and Test of High-Speed High-Interrupting-Capacity Railway Circuit Breaker

By WILFRED F. SKEATS
MEMBER AIEE

THIS PAPER describes an oil circuit breaker built to the following specifications:

Rated voltage	15,000 volts
Rated current	1,500 amperes
Frequency	25 cycles
Interrupting capacity	65,000 amperes
Over-all duration of short circuit	1 cycle

Being intended for railway trolley service, which is rather severe from the standpoint of frequency of short-circuit operation, it is expected to handle 50 short-circuit operations without internal inspection or change of oil.

Like breakers of somewhat lower interrupting rating previously supplied for this type of duty,[1] this breaker operates upon the impulse principle. A spring-driven piston forces a blast of oil across the arc, bringing about its extinction with a very small contact separation, and thus resulting in an arc of very short duration. The arrangement differs from that previously used in two important respects:

1. The earlier breakers used the radial blast, in which the oil moves in radially upon the arc and exhausts through a hole in one of the contacts; the present breaker employs the cross blast, in which a passage causes the oil to sweep directly across the arc path.

2. In order to supplement the action of the piston at high currents, a short pressure-generating break has been added. A check valve is employed to prevent the additional pressure from this break from being expended in reversing the piston.

The manner in which these operations are performed is shown in figure 1, which is a sectional view of the lower part of the breaker. While the breaker is in the closed position, the moving contact *1* presses against the intermediate contact *2*, holding it, in turn, against the stationary contact *3*. The piston *4* is at the upper end of its stroke. Upon tripping, the moving contact moves rapidly upward and the intermediate contact follows to the limit of its stroke. At the same time, force is applied to the piston and at moderately low current values it starts downward, forcing oil ahead of it down the piston cylinder up through the check values *5*, through the contact chamber, and through the horizontal passage *6* in the baffle *7*. This passage leads the oil directly across the arc path at *8* and exhausts both oil and gases from the arc into the air space at *9*. The velocity of the oil through the cross-blast passage is augmented slightly by the action of the pressure-generating break.

At high currents, the performance differs in that the pressure generated by the pressure-generating break is greater than that caused by the piston. The pressure-generating break then supplies all of the oil for the blast and the check valves remain closed and so prevent oil from the contact chamber from flowing down through them instead of through the cross-blast passage.

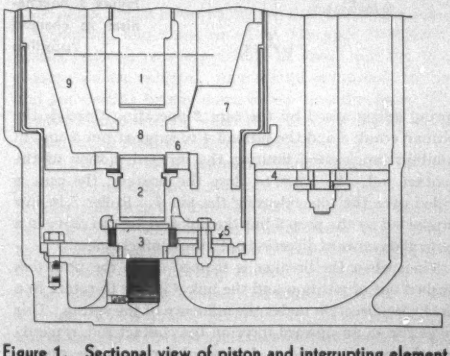

Figure 1. Sectional view of piston and interrupting element

Control of the length of the pressure-generating arc is accomplished, as shown in figure 2, by means of the metal ring *2* placed around the stationary contact *1* and so arranged that any current brought to it by the arc is led radially outward as indicated by the arrows. When the arc strikes the ring, this current path sets up a magnetic field which tends to move the arc back to the stationary contact. Thus the length of the arc can never greatly exceed the separation of the contacts.

Paper number 37-163, presented at the AIEE Middle Eastern District meeting, Akron, Ohio, October 13–15, 1937, and recommended for publication by the AIEE committee on protective devices. Manuscript submitted October 13, 1937; released for publication April 2, 1938.

WILFRED F. SKEATS is technical assistant to engineer, General Electric Company, Philadelphia, Pa.

1. For numbered reference, see end of paper.

The mechanism is similar in principle to that used in the earlier breaker. It is shown schematically in figure 3. Energy for both the closing and opening operations, as well as contact pressure in the closed position, is supplied by the spring *1*. When the breaker is charged and open, this

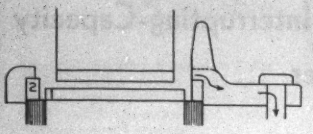

Figure 2. Arc-control arrangement at pressure-generating break

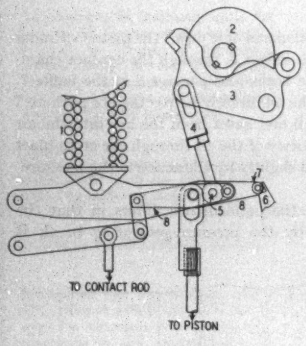

Figure 3. Mechanism in charged position

spring is restrained by the cam *2* operating through the pitman crank *3* and the pitman *4* to support pin *5*, and in combination, a stop limiting the upward motion of the contact rod. In order to close the breaker, the cam is rolled over the top, releasing the pin *5*. Roller *7* is now supported by the prop *6* but the links are free to move in a general downward direction until the contacts meet.

Then when the breaker is tripped open, the prop *6* is pushed out of position and the link *8* is free to rotate in a clockwise direction under the influence of the spring. This gives rise to an upward force on the contact rod, separating the contacts, and a downward force on the piston, creating the oil blast.

Immediately following the opening operation, a motor operating through a gear reduction mechanism turns the cam through about 300 degrees, which recharges the spring, placing the breaker in position to be reclosed in about seven seconds from the time of tripping.

The breaker and its control panel are assembled in the factory in a steel housing, with a door in front opening into the breaker compartment and a door in the rear opening upon the control panel. Figures 4 and 5 show the front and rear views with the doors open.

The testing of this breaker presented an interesting problem. In a one-cycle breaker, the severity of the duty is associated, to a large extent, with what may be called the waiting period, that is, the period after the breaker has set up conditions for clearing and while it is waiting for a current zero. It is obvious that the duration of this period is largely dependent on the frequency. Hence it is essential that the test frequency be the same as that at which the breaker is to be applied. As this was only 25 cycles while the normal testing-plant frequency is 60 cycles, the testing-plant generator had to be slowed down to about 40 per cent of its normal speed with a corresponding reduction in the output. Under these conditions the power available from the plant by the conventional testing circuit was only about 30 per cent of the breaker rating.

To overcome this situation, a special testing circuit similar to that used on the 287-kv breakers for the Boulder Dam–Los Angeles transmission line was employed. In addition to the breaker under test and the generator, this circuit comprises an auxiliary breaker with the same characteristics as the breaker under test, a transformer, a sphere gap, and, for the present tests, a synchronous closing switch, all arranged as shown in figure 6. The operation of this circuit is as follows. Initially the auxiliary breaker and the test breaker are in the closed position, and the synchronous closing switch is open. In order to initiate the short circuit, the synchronous closing switch is closed, and current flows through the auxiliary breaker, the test breaker, and the synchronous closing switch in series, and the full short-circuit current of the 3,000-volt generator connection is available. The test breaker and the auxiliary breaker both trip promptly and, in about three-quarters of a cycle, both set up conditions to clear the circuit on the next current zero.

With the breakers operating according to specification, the circuit is cleared in both at this current zero and in a few microseconds the voltage at the generator terminals

Figure 4. Breaker assembled in housing

has risen to approximately its normal peak value. This voltage is also applied at the low voltage terminals of the transformer, stepped up by the transformer in accordance with its ratio, and applied to the gap combination. This is sufficient to break down the gap and the transformer voltage is then applied to a point between the two breakers. Thus it appears directly across the test breaker. This entire process takes place, as shown by the cathode-ray oscillograph, within about 25 microseconds after the current reaches its zero value, or in about half the time required for the 10,000-cycle recovery transient to reach its first peak.

Thus, except for a period of about 25 microseconds during which no current normally flows and the voltage across the breaker is comparatively low, current interrupted by the breaker and recovery voltage are the same as in an operation at full voltage and full current.

For proper operation of the circuit, it is necessary that the gap combination should not break down appreciably before the time of current zero, and as the arc voltage when stepped up by the transformer ratio, had occasional voltage surges comparable with the recovery voltage in magnitude, a special gap arrangement was introduced to insure proper operation.

The design of this arrangement was facilitated by the fact that the breaker always interrupted after either one or two loops of current, according to the point on the voltage

Figure 5. Rear view of housing showing control panel

wave at which the short circuit struck. Since both the point on the voltage wave and the polarity of the first loop of short-circuit current were subject to control by the synchronous closing switch, it will be obvious that the polarity of the last loop was likewise controllable. The gap arrangement consisted of two sphere gaps in series shunted by equal resistances of about 120,000 ohms, but one of the two gaps was also shunted by a resistance of 1,000 ohms in series with a rectifier, the polarity of the rectifier being made such as to prevent current flow in response to arc voltage, but to permit flow in response to recovery voltage, which is of the opposite polarity.

Thus during the arcing period, the voltage is substantially equally divided between the two gaps by the higher

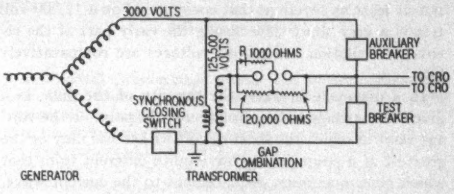

Figure 6. Special testing circuit

resistances and the combination has a maximum breakdown strength. For the recovery voltage, however, one gap is shunted by a resistance of only 1,000 ohms, so that practically all of the applied voltage appears across the other gap. When this gap breaks down, the transformer supplies voltage to the breaker through a resistance of 1,000 ohms, which is low enough so that the drop across it is negligible, and thus, in effect, the gap combination breaks down on recovery voltage at about half the value required on arc voltage. As a matter of interest, the second gap usually breaks down either immediately or after about 50 microseconds when the voltage is falling in the second half of the first recovery oscillation.

The magnetic oscillograms of figure 7 and the cathode-ray oscillogram, figure 8, indicate the performance of both breaker and circuit. Curves 3 and 6 show the short-circuit current, which has a very small minor loop followed by a large major loop. Within 0.05 cycle after the start of the major loop, the trip current responds, and at 0.6 cycle, motion of the contact rod starts (curve 2). Pressure (curve 7) is quickly generated by the primary break, and at the end of the first cycle the circuit is cleared. Curve 5 shows the voltage across the breaker, and it will be noted that the appearance of the curve immediately after interruption is no different from that corresponding to a conventional test at 12,500 volts.

The application of voltage to the breaker immediately after interruption is shown in more detail by the cathode-ray oscillogram. Two curves are shown on this record. The lower curve shows the voltage at the transformer side of the gap. Irregular oscillations occur in this curve during the arcing period; then, at the cessation of current, the voltage changes its polarity and swings into the recovery oscillation. A slight discontinuity is noticeable in this curve as it rises to the first peak of this recovery oscillation. This indicates the time of breakdown of one gap. Another discontinuity slightly after the peak indicates the breakdown of the second gap.

The upper curve shows the voltage across the breaker. During the arcing period, the deflection is barely perceptible. As the recovery voltage rises, however, the first gap breaks down and from that time on, except for a short time after the first peak when the breaker voltage is somewhat higher than the transformer voltage, the breaker voltage follows the same course as that of the voltage on the transformer side of the gaps. Thus the only period after current zero during which the voltage across the breaker is not at least as severe as that encountered on a 12,500-volt test is a very short time during the early part of the recovery oscillation when both voltages are comparatively low.

In a one-cycle breaker, the severity of the duty in a given test is likely to be a function of the point on the voltage wave at which the short circuit strikes and may be the greatest at a point on the wave quite different from that which gives maximum displacement to the current wave, or maximum root-mean-square value of the total current.

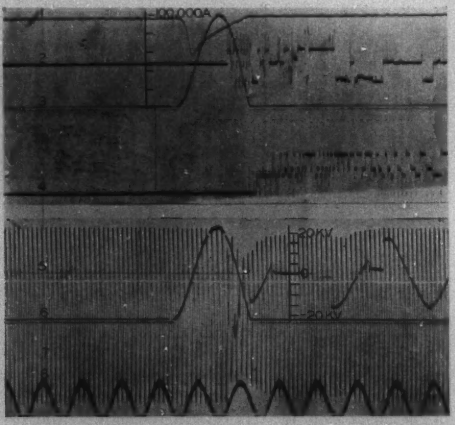

Figure 7. Magnetic oscillograms of an interruption at 12,500 volts, 60,000 amperes by special testing circuit

Curve 1—Trip-coil current
Curve 2—Contact travel: one-fifteenth inch per step
Curve 3—Current through breaker
Curve 4—Piston travel: one-fifteenth inch per step
Curve 5—Voltage across breaker
Curve 6—Current through breaker
Curve 7—Pressure in contact chamber
Curve 8—Timing wave—60 cycles

This was the case with the present breaker, and may be explained roughly as follows.

It may be expected that the severity of the duty will be a more or less direct function of the gas generation. This will depend approximately upon the ampere-seconds from the time of contact separation to the time of interruption, which will usually be the next current zero. Now when there is decay of the d-c component, as is always the case, and the contacts separate about 0.6 cycle after the inception of short circuit, the situation is as shown in figure 9. Here curve *a* shows a current wave initially fully displaced, and curve *b* a current wave about 50 per cent displaced, with the minor loop first. While curve *a* gives a higher root-mean-square value of current measured over the full duration, it comes to zero, on account of the decrement, somewhat before a full cycle has elapsed, and runs below curve *b* from 0.65 cycle on. Thus it gives a lower value of ampere-seconds in the arc than curve *b*. The greatest internal pressures were found to be generated in the breaker

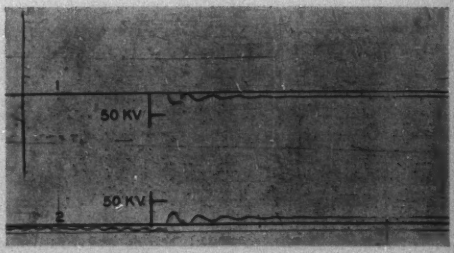

Figure 8. Cathode-ray oscillogram taken with figure 7

Curve 1—Voltage across test circuit breaker
Curve 2—Voltage at transformer side of gap

in cases similar to curve *b*, and, as will be seen in the tabulation of tests given below, care was taken that this particular condition was well represented in the test series.

As railway service is likely to involve more frequent short-circuit operations than either central-station or industrial service, these breakers were built to withstand a large number of short-circuit interruptions and the breaker was subjected to the complete series of tests shown in table I without changing contacts or oil.

In all but one of these tests, the fault was cleared within one cycle after its inception. This exception was one of

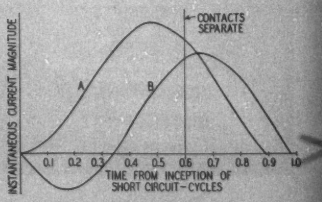

Figure 9. Comparison of fully displaced current wave with 50 per cent displaced wave having minor loop first

the light-current tests which started with a minor loop too small to trip the breaker. The breaker tripped on the second loop, however, and cleared the circuit on the third.

Figure 10 shows the condition of the contacts after test, and it will be noted that the burning is quite moderate for

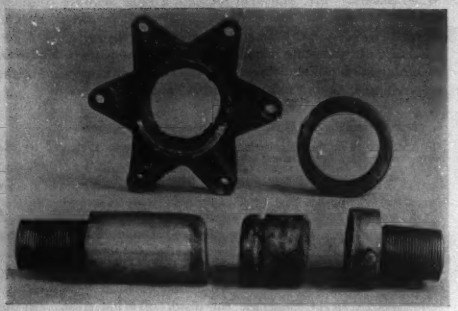

Figure 10. Contacts from impulse oil circuit breaker, 15,000 volts, 1,500 amperes, after test

the large number of severe short circuits interrupted.

Following the short-circuit tests, and without changing the oil or any breaker parts, a high-potential test was applied to the breaker resulting in a breakdown at 49 kv. The path at this breakdown, however, was through a hole which was drilled in the insulating lining to permit pressure measurement during the interrupting-capacity tests and when a sound lining was used together with the oil

Table I. Tests

Number of Tests	Opening or Closing-Opening	Voltage	Current	Testing Circuit	Point on Voltage Wave
10	CO	12,500	3,400– 5,500	Conventional	Random
20	CO	3,000	38,000–70,000	Conventional	Random
10	O	3,000/12,500	36,000–68,000	Special	Equally spaced over 180 degrees
10	O	3,000/12,500	Approx. 40,000	Special	Selected for highest tank pressure
4	O	3,000/12,500	Approx. 67,000	Special	Selected for maximum displacement

from the interrupting-capacity tests, the breaker withstood 54 kv for 55 seconds.

After the first high-potential test, a heat run was made on the breaker, using the burned contacts and the dirty oil, with a maximum temperature rise of 28 degrees centigrade.

Conclusions

On the basis of the foregoing, the following conclusions may be drawn:

1. In an exceptionally thorough test program the breaker has shown itself adequate for the severe service for which it is intended, interrupting currents from 3,000 amperes beyond its rating of 65,000 amperes within one cycle, over 50 times without inspection of contacts or change of oil.

2. The testing scheme used, by a four-to-one increase of effective plant capacity, has more than overcome the handicap which the low frequency placed upon the testing plant.

Reference

1. THE IMPULSE HIGH SPEED CIRCUIT BREAKER, W. K. Rankin. *G. E. Review*, volume 34, October 1931, pages 553–8.

Discussion

J. B. MacNeill (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): The method of testing oil circuit breakers with a high current at low voltage followed immediately after the interruption by the superposition of high voltage across the open contacts of the switch is questionable, because the conditions in the arc as the current approaches zero are different when this scheme is employed from the conditions that would apply under a circuit giving the same amount of current at the high voltage initially. We are all hoping that ways will be found for improving circuit breakers for large interrupting capacities by the use of relatively small testing equipments, as the handling of switchgear business with a normal cost probably will demand something of this kind for the future. The greatest care must be used, however, to assure reliability of such "synthetic" methods.

A review of past test experience will throw some light on this subject. It is definitely known that test circuits vary in severity and that circuit interrupters which are wholly adequate on some circuits are entirely inadequate on others. The speed of restored voltage and the maximum value to which restored voltage goes are major factors. However, the condition in the arc as the current approaches zero is influenced by the voltage available across the circuit during the interruption and must be given consideration.

Let us look at data taken on the same circuit breaker on two different test laboratories with practically the same applied voltage and approximately the same currents interrupted. Table I shows such a comparison, with the arcing time on the more severe laboratory averaging 3.2 cycles and on the less severe laboratory averaging 2.1 cycles. Again, table II shows a similar comparison on a circuit

Table I. Low-Current Tests

100,000 Kva, 15-Kv Breaker

	Laboratory 1			Laboratory 2		
Test number	35702	35703	2-5807	2-5809	2-5809	2-5810
Voltage	12,000	12,000	13,200	13,200	13,200	13,200
Current (amperes)	830	830	900	900	1,200	1,200
	880	1,060	Three	Three	Three	Three
	870	1,300	Phase	Phase	Phase	Phase
Duration of arcing (cycles)	2.0	2.5	3.0	3.0	3.5	3.5
	2.0	2.0	2.5	3.5	3.5	3.0
	2.0	2.0	3.0	3.5	3.0	3.5
Average current	960			1,050		
Average arcing time	2.1			3.2		

Table II. Medium-Current Tests

	Laboratory 1			Laboratory 2		
Test number	35706	35707	2-5811	2-5812	2-5813	2-5814
Voltage	12,000	12,000	13,200	13,200	13,200	13,200
Current (amperes)	2,870	3,120	2,500	2,500	3,500	3,500
	2,910	2,410	Three	Three	Three	Three
	3,200	3,060	Phase	Phase	Phase	Phase
Duration of arcing (cycles)	2.0	2.0	3.3	3.5	3.0	3.0
	1.5	2.0	3.5	3.5	3.0	3.5
	1.5	2.0	3.5	3.5	3.0	3.5
Average current	2,960			3,000		
Average arcing time	1.8			3.3		

breaker tested in the same two laboratories with the same applied voltage and approximately the same currents interrupted. Here the average arcing time on the more severe laboratory is 3.3 cycles on a 60-cycle circuit and on the less severe laboratory is 1.8 cycles.

These differences in arcing times result in wide differences of arc energy as the last half cycles carry more arc energy and more destructive effects on the contacts and oil. If two laboratories designed for the same specific purpose of circuit breaker testing give such widely different results when operated at the same voltage and applying the same short-circuit current, then we are bound to have reservations on any wide extrapolation such as is caused by testing at a low voltage and superposing across the open contacts a voltage several times as great. If the device under test is good for the given current at the higher voltage, then of course the test method used is of secondary importance. If, on the other hand, there is doubt of the ability of the device to handle the current at the high voltage, very little added assurance is given of the ability of the device by the superposed voltage method.

A preferred method of demonstrating the ability of higher power interrupters is that of dividing the interrupting device into several duplicate parts, each of which can be separately demonstrated to the limit of capacity to which it will be subjected on the complete apparatus. This requires means for assuring proper division of the duty between the several units, but such means have been adequately developed. For the present, however, service requirements do not call for extended subdivision of interrupting devices so that this method also like the one discussed by Mr. Skeats is of limited application.

Any assumption made from tests on 3,000 volts alternating current looking toward verification of higher voltage devices must be carefully reviewed. Three thousand volts alternating current is easy to switch, especially at high current. Under oil a plain break one inch long is adequate. Even in open air certain modifications of standard carbon breakers will do the work. This however, gives no feeling of security regarding 12,000-volt operation, which is a more difficult problem.

W. F. Skeats: Mr. MacNeill presents a table showing considerable difference in the arcing times of the same breaker in tests in different laboratories, claiming this difference as evidence of unreliability of the testing method described in the paper. However, an examination of the differences in testing conditions which might be responsible for this difference in behavior reveals three:

1. A probable difference in the rate of rise of recovery voltage;
2. A difference in the magnitude of recovery voltage as evidenced by the higher test voltage in the second laboratory;
3. A somewhat higher system voltage during the period of current flow.

Of these, items 1 and 2 are admitted by Mr. MacNeill to be of major importance, and they may be well simulated in the testing method described. The third item must derive what effect it has from any distortion introduced into the current wave by the increase in the relative importance of the arc voltage when the system voltage is decreased. In the usual case, this distortion is not great. On the basis of the evidence presented, therefore, it appears that the important differences in Mr. MacNeill's test conditions are those which can be readily taken care of in the test method described in the paper.

Again, Mr. MacNeill points out that 3,000 volts alternating current is easier to switch than 12,000 volts and that any assumption based on tests at the lower voltage must be carefully reviewed before being accepted as valid with reference to performance of the tested device at the higher voltage. This is of course true, but here Mr. MacNeill does not even make the statement that the difference does not lie in the recovery characteristic, which is certainly where it is to be expected and which is simulated by the test method described.

As a matter of fact, a few tests made on an early arrangement of the breaker by the conventional method and also at the same voltage and current, by the scheme described indicate this scheme to be somewhat more severe than the conventional method. This is attributed to the fact that this scheme overemphasizes the increase caused by the arc voltage amplitude of the recovery oscillations.

Printing Telegraph Operation of Way Wires

By G. S. VERNAM
ASSOCIATE AIEE

Synopsis: Although most commercial telegraph trunk circuits have been operated by printing telegraph methods for some years, Morse operation has been generally adhered to on way wires. Arrangements for operating way wires by printing telegraph have been developed, and are described. These include a polar simplex system, a neutral way-wire system, a code calling bell arrangement, and a multistation customers' printer circuit that provides secrecy by preventing the connection of more than one customer's printer to the line at a time. The paper also describes a new single-line repeater arranged to repeat polar as well as neutral signals, and a "dotter" for transmitting uniform test signals.

COMMERCIAL telegraph messages are transmitted between major cities over a network of trunk lines, usually operated by the multiplex printing telegraph method. These trunks terminate at main "relay offices" of the telegraph company, from which lines radiate to smaller cities and towns. Some of these radiating lines are direct trunks to cities having a considerable amount of traffic, and are equipped with start-stop printers, operated either single or duplex. In other cases, the traffic to a single place is not enough to justify exclusive assignment of a line conductor, and intermediate offices or "way stations" are connected into the circuit to increase the traffic load. Such circuits are called way wires.

The manual or Morse method of operation has been used on these way wires, because of its simplicity and low line-signal frequency and because of the cheapness and ease of adjustment of the apparatus. The way-station operator will usually be the manager of the office, and to provide continuous service a second operator should be available to cover lunch periods and to permit the manager to take care of other business.

The advent of telephone train dispatching and the increasing use of printers on commercial telegraph circuits and on private leased wires has reduced the supply of available Morse operators, so that it is becoming difficult to obtain Morse operators. It is usually better to hire a suitable manager, who can be trained easily and quickly to operate a printer. A messenger can learn in a short time to operate a printer well enough to act as relief operator. It is evident, therefore, that it is desirable in many cases to substitute printer operation of way wires for Morse.

Another use for printing telegraph operation of multistation circuits is for connecting private customers' offices to a telegraph office, where the customers are located at a considerable distance from the telegraph office, but are so placed that they can be connected in series on a single circuit. The total traffic received from all customers may justify the cost of such a line, where it would be uneconomical to provide a separate line to each customer. In such cases, the system must be so arranged that messages to or from any customer cannot be copied by other customers' printers on the same circuit.

Multistation Leased Lines

By "leased line" is meant the type of circuit used for so-called "private wire service," where a subscriber contracts for the exclusive use of a telegraph circuit, over which he transmits and receives his own messages. Multistation leased lines have some points of similarity with the commercial telegraph way wires discussed in this paper, but in other respects their requirements are quite different. A previous paper[1] describes this "private wire service" and points out the fact that the start-stop printer or teletypewriter is particularly suitable for this type of service because of its simple sending, receiving, and timing arrangements, and its automatic ability to take care of varying lags in signals transmitted from any sending station to any receiving station. For the same reasons, the start-stop printer is suitable for way wires.

In many cases the messages sent from any station on these private leased-wire circuits are intended to be recorded at all other stations, as, for example in the case of press or police circuits. In other cases, messages are intended for a particular station and it may be desirable to use a selective calling arrangement. The Gill telegraph selector[2] has been used in some cases for automatically starting and stopping the printer motor at the desired station, when the proper code signal combination is transmitted. This type of selector usually operates on all message signals that pass over the circuit, but it does not close its contacts unless a particular combination of signals is received. This continual operation of the selector mechanism causes wear and maintenance expense. This difficulty has been avoided in other selective calling systems[3] where telephone dials are used to operate step-by-step switches and relays. In these systems, the selective equipment is normally disabled while printing signals are being transmitted and is cut in by slow acting relays when the printers are shut down.

These multistation leased line circuits may extend for long distances, through several telegraph central offices where telegraph repeaters are located, with trained personnel for adjusting them. The individual stations are connected to these central offices over comparatively short loops, which present no severe transmission problems. The cost of the long line circuits and the large volume of traffic transmitted, justify the use of elaborate repeating

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1. For all numbered references, see list at end of paper.

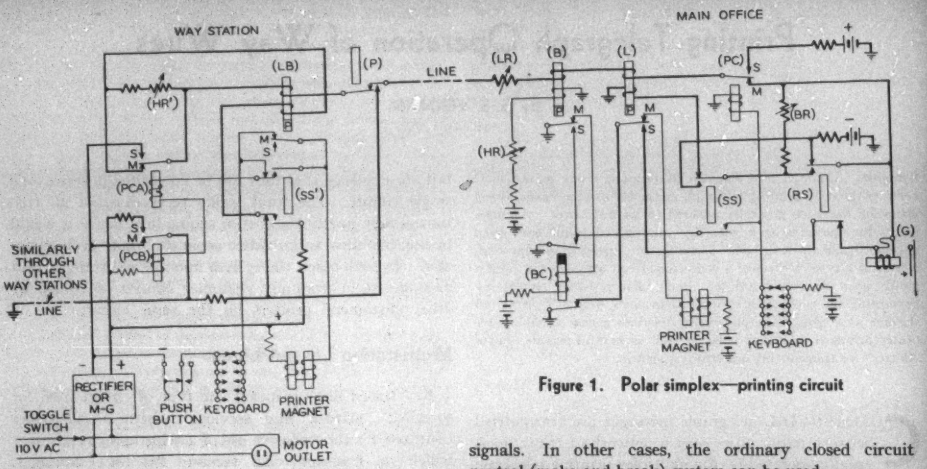


Figure 1. Polar simplex—printing circuit

and selecting equipment, if these are needed to provide good service.

Printer Way-Wire Requirements

The requirements for operating printers over commercial telegraph way wires are quite different from those for operating over private wire multistation lines. These way wires extend from a main telegraph office, through one or more intermediate "way stations," to a terminal office, which may also be considered as a way station. Traffic is exchanged between the main office and each way station, but messages are seldom, if ever, transmitted directly from one way station to another.

The way stations are usually located at a considerable distance from any main telegraph office and skilled attendants are not available for balancing duplex sets or for making any but the most simple adjustments. For these reasons, the way-station apparatus must be simple and reliable. To compare favorably with Morse operation, the cost of the equipment must be kept down, expensive selecting equipment which may require frequent maintenance attention should be avoided, and the power consumption should be reduced to a minimum.

The best wires are not ordinarily assigned to these way-wire circuits. They are usually open-wire ground-return lines and are frequently subject to severe leakage during wet weather and to induced interference from other telegraph circuits or nearby power lines. Start-stop printer signals, at the usual transmitting speed of about 60 words per minute, are approximately twice as fast as the usual Morse signals. For satisfactory printer operation, signal distortion, particularly bias, must be kept below definite limits. These factors impose severe requirements on the system of signal transmission used, and in some cases make it necessary to use polar (+ and −) signals. In other cases, the ordinary closed circuit neutral (make and break) system can be used.

Means should be provided for calling the main office from any way station and for calling any particular way station from the main office, so that the printers can be shut down when not in use. This avoids having messages intended for one way station printed at all other stations, reduces the wear on the printer mechanisms and saves power. A simple code calling arrangement, with single-stroke a-c bells, is being used instead of selectors, so that no d-c supply is required during idle intervals at the way stations, except in a few cases where it is needed at terminal way stations for line current or for operating repeaters.

Polar Simplex System

In this system,[4] polar (+ and −) signals sent from any one station are received by polar relays in series with the line at all other stations, and switching relays are provided for automatically connecting and disconnecting the source of transmitting current to reverse the direction of transmission, so that a station formerly receiving can send back to a station that was formerly transmitting. Any receiving station can "break" or interrupt the sending station, the operation of the printers being exactly the same as on a single closed-circuit line. While sending polar signals from either terminal station, the line is grounded at the other terminal station; and while sending polar signals from an intermediate station, the line is grounded at both terminal stations. Whenever sending stops, the circuit returns to the normal, idle condition, with line current supplied from the main office.

While the circuit is idle, all printer motors can be switched off, as well as the power rectifiers at all way stations. Any way station can call in, operating a signal lamp and buzzer at the main office, and the main office can call any way station by operating a single-stroke bell at each station.

Figure 1 is a simplified diagram of that part of the circuit

that is concerned with sending and receiving printer signals. It shows a main office and one way station. The line may extend through several way stations, but as they are identical, only one is shown. Certain parts, such as call bells, signal relays, and the local operating circuits of the switching relays have been omitted from this figure to simplify the drawing.

Negative "marking" battery is normally connected to the line at the main office. When the keyboard is operated, pole changer *PC* transmits (+) spacing and (−) marking signals over the line. Polar line relay *L* responds to these signals and operates the main office printer. Polar relay *LB* at the way station also responds and operates the way station printer. Switching relays *SS* and *RS*, at the main office, operate and remain operated until transmission stops. They have no effect however except to open the biasing winding circuit of relay *L*. Break relay *B* is held by a current through its lower winding equal to about one and one-half times the line current. If the line circuit has considerable capacity, line current surges may operate this relay momentarily at the beginning of each spacing signal, but this will have no effect, as relay *BC* is of the slow-release type and the short circuits momentarily applied by relay *B* to relay *PC* occur at a time when its operating circuit is open at the keyboard.

Signals sent from the way station keyboard operate the printer magnet as well as pole changers *PCA* and *PCB*. Switching relay *SS'* operates during the first spacing signal and remains operated until the way station operator stops sending. It switches the marking contact of *PCA* from ground to the (+) terminal of the rectifier. The rectifier is connected in series with the line and is reversed by the pole changers to transmit polar signals over the line toward the main office and also over the line toward the terminal way station. It should be noted that the direction of current in the line, for marking and spacing signals, respectively, is the same regardless of whether the main office or a way station is sending.

Relay *LB* does not respond to signals from the pole changers at its own station, as marking signals transmitted through both windings in series hold its armature against the marking contact, and spacing signals are sent to line through only one winding while marking current continues through the other winding and is adjusted by rheostat *HR'* to be about one and one-half times the line current. As in the case of relay *B*, relay *LB* may be operated momentarily by spacing current surges due to line capacity. This will open the circuits of the printer magnet and pole changers at a time when they are already open at the keyboard contacts.

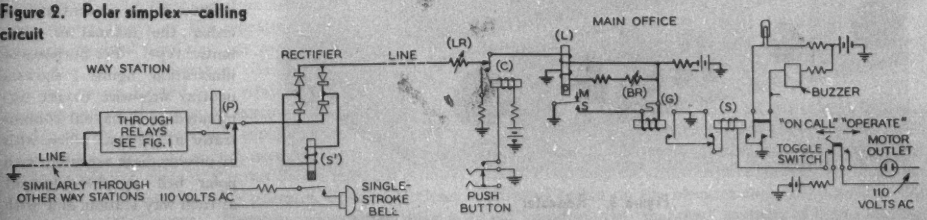
As (−) battery is normally connected to the line at the main office, the first spacing signal from the way station reduces the line current approximately to zero, at first, instead of reversing it. Relay *L* is now operated, however, by biasing current through its lower winding, regulated by rheostat *BR* to be only slightly less than the normal line current. Relay *L* immediately grounds the line through the winding of relay *G*, allowing the line current to reverse. Relay *G* operates switching relay *RS* (over circuits not shown). Relay *RS*, which remains operated as long as relay *L* responds to signals, disconnects the (−) battery from the line and grounds the line through both windings of relay *L*. Relay *L* operates the main office printer magnet causing the printer to record the message being transmitted from the way station.

When the way-station operator stops sending, relay *RS* releases and applies battery to the line at the main office and relay *SS'* releases and disconnects the rectifier from the marking contact of *PCA* at the way station, so that the circuit is automatically restored to its normal idle condition with line current fed only from the main office. Relay *RS* is timed so that it always releases before relay *SS'*, so that marking signal current is always applied to the line at the main office before it is removed at the way station. If the way station operator sends in a slow or hesitant manner, relay *RS* may release occasionally during the message. The momentary double strength marking current will have no bad effect, however, as relay *RS* applies the bias current to relay *L* at the same time.

Relay *P* is operated by direct current from the rectifier. It serves to disconnect the way station printer set from the line when the power is switched off. The arrangement is such that any way station set can be switched on and off without momentarily opening the line or otherwise interfering with other stations that may be using the line.

Any station can interrupt transmission from another station by operating any key on the keyboard several times in succession or by opening the keyboard circuit with a push button "break" key such as that shown at the way station. When a spacing signal from the "breaking" station occurs at the same time as a spacing signal from the transmitting station, the double strength current in the line operates the armatures of the *B* and *LB* relays to their spacing contacts, overcoming the holding currents through rheostats *HR* and *HR'*. Relay *LB* releases pole changers *PCA* and *PCB* as well as the printer magnet. As long as the double-strength current continues, the

Figure 2. Polar simplex—calling circuit



contacts of relay *LB* will remain open and the pole changers and printer magnet will remain released, thus giving a definite indication of the break signal at the way station.

At the main office, relay *L* opens the printer magnet circuit to indicate the break at that station, relay *B* releases relay *BC* and both relays connect a ground through contacts of relay *SS* to short-circuit pole-changer *PC*. The double strength break current continues, therefore, as long as relay *SS* remains operated. When the main office operator stops sending on the keyboard, relay *SS* releases and allows pole changer *PC* to operate and send marking current to the line. This allows relays *B* and *LB* to operate and restore the circuit to normal.

Figure 2 shows the calling-signal arrangement. This apparatus is included in the line circuit of figure 1, but is shown in a separate diagram to simplify the drawings. Slow-release relay *S'* at each way station is connected to the line through a small copper-oxide rectifier so that the line current always flows in the same direction through the relay. This relay remains operated on all printing signals but releases when the line current is stopped by depressing the push button at the main office. The main station can operate the call bells at all way stations, regardless whether the power is turned on the way station sets or not.

To call the main office, the operator at any way station switches on the local power and depresses the push button or any key on the keyboard. Relays *L*, *G*, and *S* respond to operate the buzzer and light the signal lamp at the main office. These signals are released when the main office operator turns on the printer motor to answer the call.

The only operating adjustments required with this system, are the settings of the three rheostats at the main office and the one rheostat at each way station. If properly adjusted, when the circuit is first installed, they usually require no further adjustment, except that, in cases where considerable interference or very heavy leakage is experienced, it may be necessary to readjust bias rheostat *BR*, at the main office, occasionally. The adjustments of break holding rheostats *HR* and *HR'* are not critical, and even if incorrectly adjusted they are not likely to affect the operation of the printers but they may interfere with the proper action of the "break" feature.

The main-office circuit can be arranged so that the circuit can be extended through a concentrator to one of a group of main-office printers or over a duplexed line or carrier circuit to a distant city. The concentrator permits grouping the polar simplex way wire with other lightly loaded circuits and connecting these circuits to the main office printers, only when needed for sending or receiving messages. This reduces the number of main-office printers required and improves the operating efficiency at that office. The extension to a distant city can be used for special purposes such as the transmission of news directly from the way station without rehandling at the main office.

Neutral Way-Wire Printer System

Where line conditions are not too severe, the simpler "neutral way wire" system can be used. This system uses neutral printing signals and reversed current or polar signals for operating the call bells. If the line resistance is not too great, the line may be connected directly to ground at the terminal way station, the line current being supplied from the main office. Positive battery is normally connected to the line at the main office, and for longer lines, a reduced negative voltage can be connected to the line at the terminal way station. As this is of the same polarity as the bell signal potential at the main office, the bell signal current will be reduced to a comparatively low value, normally about 15 milliamperes, but this is sufficient to operate the sensitive polar relay that rings the call bell.

For still longer lines, a single-line repeater can be installed at an intermediate station. A special repeater for this purpose, is shown in figure 3. Ordinary single-line repeaters can repeat neutral or "make and break" signals only. If equipped with fast relays, they can be used to repeat start-stop printer signals. The repeater shown in figure 3, however, is arranged to repeat the polar bell signals as well as the neutral printing signals.

Figure 3. Repeater

At the main office, the line may be connected permanently to a printer set, if there is enough total traffic to justify it, or it may be connected to a concentrator of either the manual or automatic[6] type. For purposes of illustration, figure 4 shows a neutral way-wire circuit terminated in a manual concentrator at the main office, with an intermediate repeater, with polar bell signal equipment at each way station and with

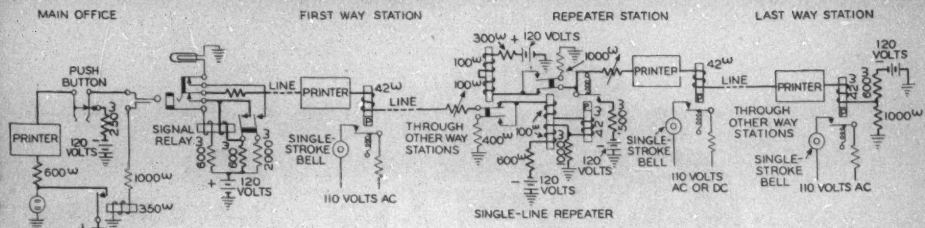


Figure 4. Neutral way-wire printer circuit with repeater

a potentiometer for supplying a reduced line potential at the terminal way station.

High-Speed Neutral Relay

The repeater uses a new fast neutral or nonpolar relay, two of which are shown mounted on the repeater in figure 3. This relay has a laminated core, an aluminum armature lever pivoted on a stainless-steel knife edge, operating two pairs of contact springs. The contacts are of molybdenum, mounted on beryllium copper springs, and are so arranged that they can be adjusted for either break-before-make or make-before-break operation. The latter adjustment is applied, when the relays are used in this repeater. The relay contact springs, and the adjustable spring, are so designed that the increase in spring tension, as the relay operates, closely balances the increase in magnetic pull, as the armature approaches the poles of the magnet core; with the result that the operate and release adjustments of the relay can be brought close together, without adjusting the airgap, as is necessary in the usual type of neutral telegraph relay. Only one simple spring adjustment is required, therefore, to adapt the relay to meet a wide range of operating conditions, including operation over lines subject to considerable leakage. This design and method of adjustment also maintains heavy contact pressures at all times and increases the reliability of the relay.

Single-Line Repeater

Referring to figure 4, with positive battery connected to the line at the main office, the contacts of the polar relays at the repeater and at the way stations are held open by the line current and when the line is opened and closed in transmitting printer signals they are held in the same position by their armature biasing spring. Each of the neutral relays of the repeater responds to printing signals received over one line section and repeats them into the other line section. Each relay also controls a locking circuit for the other relay to prevent it from releasing during the open or spacing intervals in the outgoing signals. As previously explained, the relay contacts are flexible, and are so adjusted that, when the relay releases spacing contact S closes before marking contact M opens, and when the relay operates, contact M closes before contact S opens. Therefore, when either relay is repeating signals, the other relay will remain continuously operated, as its circuit always remains closed, either through the M contact and line circuit or through the S contact and locking resistance. As each relay closes the local locking circuit of the other relay only during spacing signal intervals, the repeater is in condition, during marking signal intervals to transmit a "break" signal from the receiving to the sending station, thus permitting any station to interrupt transmission, if necessary.

During idle periods, any way-station operator can call by depressing his "break" key, momentarily opening the line, releasing the signal relay, and lighting the signal lamp at the main office. The main office operator responds by plugging a printer set cord into the jack and answering on the printer keyboard.

The main-office operator can call any way station by plugging in and depressing the push button the proper number of times. This transmits a reversed current of reduced strength (about 15 milliamperes) over the line operating the call bells at any way stations between the main office and the repeater. Opposing currents now flow through the two windings of the right hand repeating relay, releasing it, and the reversed current operates the polar relay, thus removing the positive potential and connecting a negative potential to the outgoing line and ringing the bells at way stations beyond the repeater.

Referring to figure 3, the single-line repeater consists of a pair of high-speed neutral relays mounted on a base or chassis, together with certain auxiliary equipment. The chassis is an aluminum-finished steel box with a detachable base plate. It contains the resistors, spark killers, rheostats, switches, and jacks and mounts a receptacle for a power-supply plug, a terminal strip for external wiring connections and sub-bases into which the relays are plugged. The polar bell signal relay is mounted on a bracket at the right side of the repeater and there is room for mounting a milliammeter, if required, at the left side. When installed at a way station, this repeater can be mounted on any convenient table or shelf, or if installed at a main office it can be mounted on a standard repeater rack.

A jack is provided in each line for inserting a milliammeter to measure the line current, which can be regulated by a rheostat. The center jack is in a local test circuit used for checking the adjustment of the relays. When the left-hand switch on the repeater chassis is turned to the "cut" position, the "marking" contacts of both repeating

contacts of relay *LB* will remain open and the pole changers and printer magnet will remain released, thus giving a definite indication of the break signal at the way station.

At the main office, relay *L* opens the printer magnet circuit to indicate the break at that station, relay *B* releases relay *BC* and both relays connect a ground through contacts of relay *SS* to short-circuit pole-changer *PC*. The double strength break current continues, therefore, as long as relay *SS* remains operated. When the main office operator stops sending on the keyboard, relay *SS* releases and allows pole changer *PC* to operate and send marking current to the line. This allows relays *B* and *LB* to operate and restore the circuit to normal.

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Neutral Way-Wire Printer System

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For still longer lines, a single-line repeater can be installed at an intermediate station. A special repeater for this purpose, is shown in figure 3. Ordinary single-line repeaters can repeat neutral or "make and break" signals only. If equipped with fast relays, they can be used to repeat start-stop printer signals. The repeater shown in figure 3, however, is arranged to repeat the polar bell signals as well as the neutral printing signals.

Figure 3. Repeater

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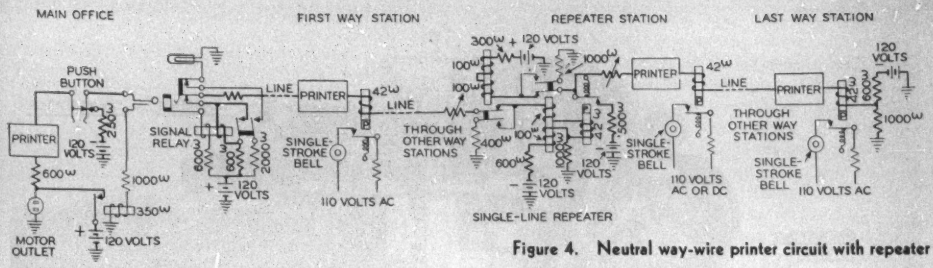

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a potentiometer for supplying a reduced line potential at the terminal way station.

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The repeater uses a new fast neutral or nonpolar relay, two of which are shown mounted on the repeater in figure 3. This relay has a laminated core, an aluminum armature lever pivoted on a stainless-steel knife edge, operating two pairs of contact springs. The contacts are of molybdenum, mounted on beryllium copper springs, and are so arranged that they can be adjusted for either break-before-make or make-before-break operation. The latter adjustment is applied, when the relays are used in this repeater. The relay contact springs, and the adjustable spring, are so designed that the increase in spring tension, as the relay operates, closely balances the increase in magnetic pull, as the armature approaches the poles of the magnet core; with the result that the operate and release adjustments of the relay can be brought close together, without adjusting the airgap, as is necessary in the usual type of neutral telegraph relay. Only one simple spring adjustment is required, therefore, to adapt the relay to meet a wide range of operating conditions, including operation over lines subject to considerable leakage. This design and method of adjustment also maintains heavy contact pressures at all times and increases the reliability of the relay.

Single-Line Repeater

Referring to figure 4, with positive battery connected to the line at the main office, the contacts of the polar relays at the repeater and at the way stations are held open by the line current and when the line is opened and closed in transmitting printer signals they are held in the same position by their armature biasing spring. Each of the neutral relays of the repeater responds to printing signals received over one line section and repeats them into the other line section. Each relay also controls a locking circuit for the other relay to prevent it from releasing during the open or spacing intervals in the outgoing signals. As previously explained, the relay contacts are flexible, and are so adjusted that, when the relay releases spacing contact S closes before marking contact M opens, and when the relay operates, contact M closes before contact S opens. Therefore, when either relay is repeating signals, the other relay will remain continuously operated, as its circuit always remains closed, either through the M contact and line circuit or through the S contact and locking resistance. As each relay closes the local locking circuit of the other relay only during spacing signal intervals, the repeater is in condition, during marking signal intervals to transmit a "break" signal from the receiving to the sending station, thus permitting any station to interrupt transmission, if necessary.

During idle periods, any way-station operator can call by depressing his "break" key, momentarily opening the line, releasing the signal relay, and lighting the signal lamp at the main office. The main office operator responds by plugging a printer set cord into the jack and answering on the printer keyboard.

The main-office operator can call any way station by plugging in and depressing the push button the proper number of times. This transmits a reversed current of reduced strength (about 15 milliamperes) over the line operating the call bells at any way stations between the main office and the repeater. Opposing currents now flow through the two windings of the right hand repeating relay, releasing it, and the reversed current operates the polar relay, thus removing the positive potential and connecting a negative potential to the outgoing line and ringing the bells at way stations beyond the repeater.

Referring to figure 3, the single-line repeater consists of a pair of high-speed neutral relays mounted on a base or chassis, together with certain auxiliary equipment. The chassis is an aluminum-finished steel box with a detachable base plate. It contains the resistors, spark killers, rheostats, switches, and jacks and mounts a receptacle for a power-supply plug, a terminal strip for external wiring connections and sub-bases into which the relays are plugged. The polar bell signal relay is mounted on a bracket at the right side of the repeater and there is room for mounting a milliammeter, if required, at the left side. When installed at a way station, this repeater can be mounted on any convenient table or shelf, or if installed at a main office it can be mounted on a standard repeater rack.

A jack is provided in each line for inserting a milliammeter to measure the line current, which can be regulated by a rheostat. The center jack is in a local test circuit used for checking the adjustment of the relays. When the left-hand switch on the repeater chassis is turned to the "cut" position, the "marking" contacts of both repeating

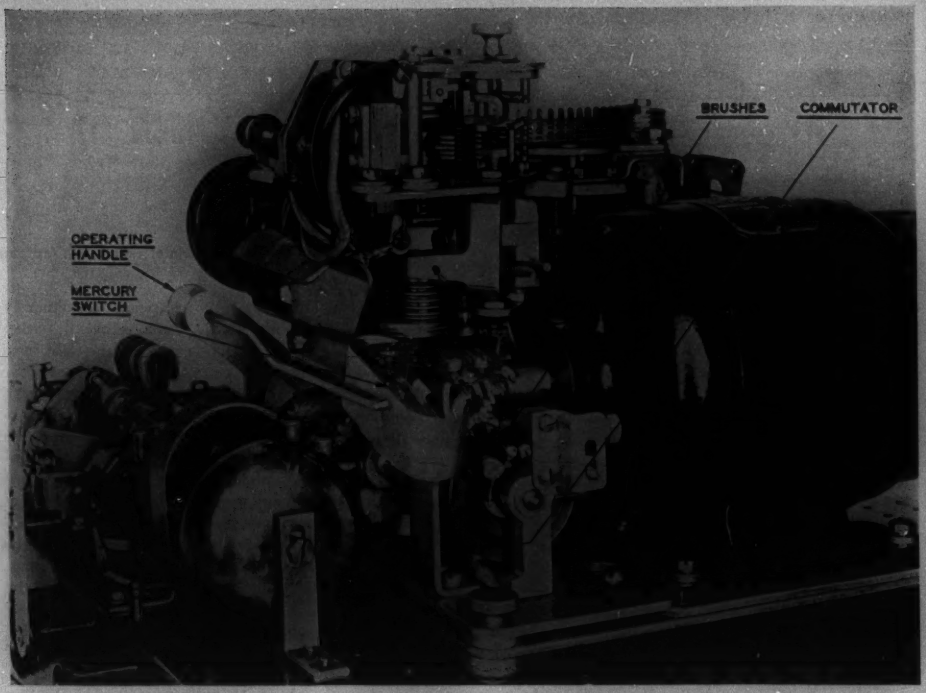

Figure 5. Rear view of printer with dotter attachment

relays are connected in series with this local test circuit. To line up the repeater, the current is measured in this local test circuit and then uniform dot signals are transmitted from an interrupter or "dotter" at the main office. The armature spring of the repeating relay is then adjusted until the milliammeter indicates half the closed-circuit current in the local test circuit. Dotter signals are then sent from the terminal way station to adjust the other repeating relay in the same way. The adjustment should be checked for both wet and dry weather conditions. It has been found that, in most cases, a mean adjustment can be obtained that will operate satisfactorily for long periods without change.

Figure 5 shows a "dotter" that will transmit uniform signals at the same frequency as the printer signals. To reduce its cost, it has been designed as an attachment to a standard tape printer. It consists of a small commutator driven by the printer motor. A link extending to the front of the printer lifts the brushes off the commutator and tilts a mercury switch to short-circuit the dotter when it is not in use.

Figure 6 is an oscillogram illustrating the action of the repeater in repeating printing telegraph signals. The upper curve shows signals as received by the repeater over an artificial open wire line equivalent to 260 miles of number 9 (American Wire Gauge) copper with leakage of one megohm per mile. The signals were transmitted from a "dotter" at a speed of 50 dots per second (100 bauds), which is approximately twice the usual printer signal speed. The lower curve shows the outgoing signals as repeated into a noninductive resistance circuit. It should be noted that, although the windings of one relay are included in the outgoing line, the inductance of the windings does not prevent the outgoing signals from having an approximately square wave shape. This is because the winding always has current through it, as previously explained, and there is no large change in the current through the relay while the other relay is acting to repeat signals. In this particular case, the relay-locking current was slightly greater than the normal line current, and the inductance of the relay winding has an effect opposite to that usually expected. It causes the line current to rise rapidly at the start of each closed circuit signal to a value approximately equal to the locking current. Even if the inductance of another relay or printer magnet is included in the outgoing line, the outgoing signals will more closely approach a square wave shape than if they were transmitted directly into the outgoing line without going through the repeater.

These oscillograms are included solely for the purpose of

illustrating the action of the repeater and do not represent the extreme conditions as regards signal speed, etc., under which the repeater can operate.

Two-Wire System With Secrecy Feature

In the previously described systems, the printer can be turned on at any way station to copy messages being transmitted by other stations. This prevents their use for circuits to private customers where privacy is required. To meet the need for a multistation line for connecting customers' printers to a main telegraph office, the circuit shown in figure 7 was developed, and has been used for the last year and a half. As previously mentioned, this arrangement is suitable for cases where the customers' stations are so located that they can be connected in series along a line. It can also be used, to advantage, where customers' stations are located in a group close together but at a considerable distance from the telegraph office.

The number of stations that can be connected on one circuit is limited only by the amount of traffic to be handled. Too many stations should not be connected to one circuit, so as not to delay appreciably any customer's messages. The circuit is normally arranged for a maximum of ten way stations, but could be readily modified to accommodate more.

This circuit requires two wires, which extend from the main office, in series through the way stations to ground. One of these wires, the "control" wire, is used for transmitting calls from the way stations to the main office and for controlling, from the main office, the starting and cutting in of the printer at any particular way station. The second wire, the "printing" wire, is used for transmitting printer signals and for stopping the printer motors and cutting out the way-station printers.

A special form of selector is used at the way stations, consisting of two contacts operated by cams on the shaft of a small self-starting synchronous motor. The motor is somewhat like an ordinary electric clock motor and has reducing gears such that the cam shaft runs at a speed of four rpm. One of the cams is permanently fixed to the shaft, and its contacts serve the purpose of insuring that the motor cam shaft will make a complete revolution after it is started. The second cam is adjustable, and is set at a different position at each way station. Its contact serves to operate the motor-control relay, if the proper signal is received from the main office. A somewhat similar device is used as a sending selector at the main office. This has, in place of the adjustable cam, a distributor or commutator, with one segment for each station to be selected. A manually operated ten-point switch is provided to connect the transmitting circuit to the particular segment corresponding to the desired station.

To call a way station, the main-office operator first sets the ten-point switch to the terminal corresponding to the desired station and then operates the key to the "call" position. This applies positive potential through the main office printer to the printing wire, releasing the "stop" relays and lighting the busy signal lamps at all stations. It also closes a circuit to start the sending selector motor. Immediately after it starts, a cam contact closes, to insure that the shaft will make a complete revolution. When the brush crosses segment *S*, the sending relay is operated momentarily, thus sending a positive impulse over the control wire and momentarily operating the "start" relay and the "selecting" relay at each way station. The start relays start the receiving selectors, and the cam contacts insure that their shafts make a complete revolution. After the start impulse, the sending relay sends negative current to the control wire until the sending selector brush crosses the segment selected by the ten-point switch, when a brief positive impulse is transmitted, momentarily operating the start and selecting relays again.

At the desired station, the contact spring drops into the notch of the adjustable cam while this positive impulse is being received. At this station the motor-control relay operates and locks itself, starting the printer motor and removing a short circuit from the printer. At all other way stations, the adjustable cam is set at a different point, and, therefore, the motor control relays do not operate. At the main office, the control relay operates in series with the sending relay, at this time. It locks itself through the key contacts, starts the printer motor, and opens the starting circuit of the selector motor. After transmitting the positive selecting impulse, the sending relay continues to send negative current over the control wire, as the selector brush continues its revolution to the stopping point.

The milliammeter indicates a slight reduction in current at the instant when the way station printer is cut in. This occurs at the same time as the starting of the main office printer motor, and indicates to the operator that the way station selector has responded properly to the call. Messages can now be transmitted.

Figure 6. Oscillogram of repeater signals at 50 cycles per second

It should be noted that the starting of the customer's printer motor is controlled entirely from the main office and that no customer can start his own printer motor or remove the short circuit from his printer magnet. Therefore, only one customer's

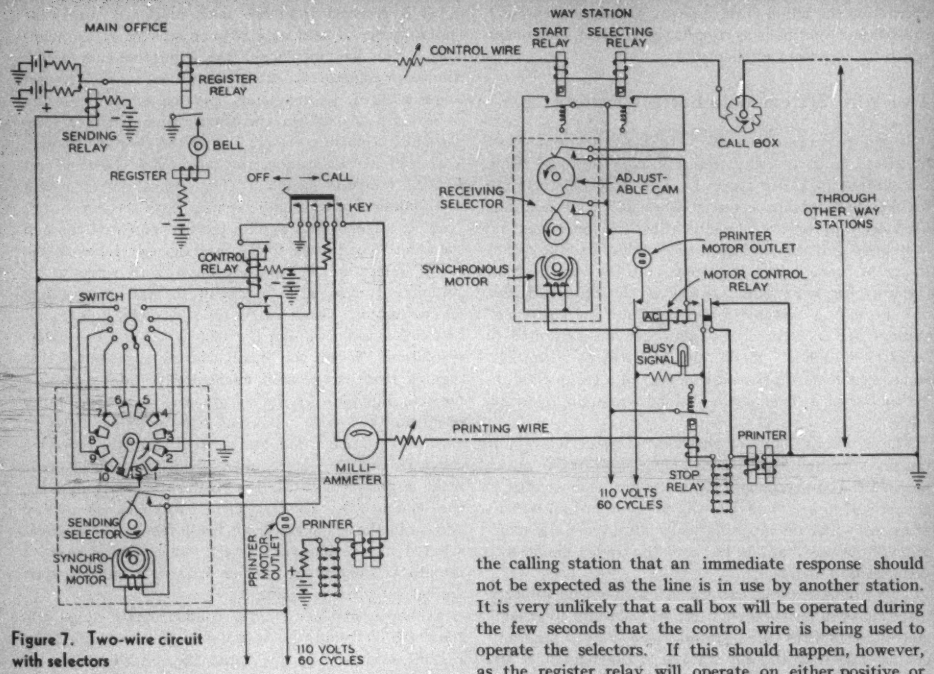

Figure 7. Two-wire circuit with selectors

printer can be connected, in operating condition, to the line at a time and it is impossible for one customer to copy another customer's messages. The control equipment is installed in a locked box to prevent tampering with it.

After the messages have been sent and acknowledged, the operator restores the key, thus releasing the control relay, stopping the main office printer motor, and applying negative potential to the printing wire. This operates the "stop" relays at all way stations, extinguishing the busy lamps and releasing the motor control relay to cut out the previously selected station. The key must be restored to the "off" position, and reoperated, in order to start the sending selector, if another way station is to be called immediately. This prevents the operator from calling a second way station by mistake, without first cutting out the station previously called.

Any way station can call the main office by operating the call box. This is like an ordinary messenger call box and transmits a series of open circuit impulses, different for each station. These impulses operate a single stroke bell and a tape register at the main office, and the signal indicated by the bell and recorded on the tape identifies the particular way station that called. In response to such calls, the main office operator selects and calls this station in the same manner as for sending outgoing messages.

It should be noted that calls can be sent in and registered while the line is busy. The busy signal indicates to the calling station that an immediate response should not be expected as the line is in use by another station. It is very unlikely that a call box will be operated during the few seconds that the control wire is being used to operate the selectors. If this should happen, however, as the register relay will operate on either positive or negative current, and as the call-box signals are much faster than those sent out by the sending selector, such calls will be correctly received and usually will not interfere with the proper operation of the selectors. Even if they should prevent the proper starting of the motor at the called station, the milliammeter will indicate this to the main office operator, who can repeat the call by restoring and reoperating the calling key. In any case, incoming calls cannot cause the selection of a wrong station.

Conclusions

The conversion of way-wire circuits from Morse to printer operation has been retarded by lack of suitable, simple, and reliable equipment for operating such circuits, for calling individual way stations and for preventing one way station from recording messages intended for another. It is expected that the apparatus and systems described in this paper will meet this demand and permit more rapid expansion of printer way wires.

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A New Type Vacuum Seal

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Synopsis: A new type of lead-in structure for vacuum-, gas-, or oil-tight chambers is described in which porcelain bushings are sealed to metal by means of a glass which serves as a bonding agency. The method of assembly is extremely simple, requiring no skilled workmen or elaborate equipment. Some of the features and some of the places where the seal is being applied are discussed.

Introduction

THE PROBLEM of bringing insulated electrical conductors into metal containers which must be hermetically sealed, oil-tight, or vacuum-tight, has for many years been a formidable one. This is attested by the large number of methods now in use, the voluminous literature on the subject and the many patents which have been issued. The most obvious type of lead-in construction is of the gasket type, where a porcelain or glass insulator is used with gaskets between the metal and the porcelain. The whole assembly is held together by some compression arrangement, and the seal depends for its effectiveness upon a tight fit between the metal and gasket, and the ceramic and the gasket. Seals of this type have always been extremely difficult to make perfectly tight. Usually the gasket material, or the structure, is such that it is impossible to heat them to even a few hundred degrees without ruining them. Consequently, it has long been recognized that the most desirable type of lead-in structure is one in which the porcelain, glass, or other ceramic which is used for the insulator, is actually sealed to the metal, either directly or by means of an intermediate sealing material. Seals of this type may be conveniently divided into four classes as follows:

I. Glass or porcelain sealed to metal by means of resins or gums.
II. Glass or porcelain metalized and attached to main metal member by means of low-melting-point metal alloys.
III. Glass sealed directly to metal.
IV. Porcelain sealed to metal by means of a glass.

Seals in class I may be made using ceramics and metals of quite different expansion characteristics due to the plasticity of the resins or gums. They are limited to low temperature applications.

Seals in the second class are usually made between a metal and porcelain which do not match in expansion. The bond is made at the melting point of the alloy and upon cooling to room temperature the structure is quite highly stressed due to the difference in expansion of the components. It is essential that the seals are so designed that all high stresses in the porcelain are compression, as the ceramic materials are very strong for that type of stress.

Seals of this type are mechanically strong and are used extensively, but they are limited to moderate temperatures due to the low melting point of the sealing alloy.

There are many different seals which fall into class III. One of the early seals of this type was made by Housekeeper.[1] At the time this type of seal was developed, available metals, which could be easily worked and glasses were of widely different coefficients of expansion. Under most conditions, if they were fused together at the high temperature necessary to work the glass, the stresses which resulted upon cooling due to the differences in expansion caused the glass to crack. Housekeeper circumvented this difficulty by using a metal which had a low yield point, (copper) and thinning it to a very small section where it sealed into the glass. In this way he caused the metal to flow and prevented the development of further stress in the glass before the stress in the glass reached a high enough value to cause it to crack. One of the main disadvantages of this type of seal, however, is the weakness caused by the thinning of the metal member.

Many advances have been made in the science of sealing metals to glasses, due primarily to the fact that various metals and alloys have been developed which have coefficients of expansion matching those of certain glasses.

One of the greatest and most recent advances in the field is due to H. Scott.[2] From his study of the low expansion anomaly of the iron-nickel-cobalt alloys,[3,4] he found that one particular alloy, which he called Kovar (Patent No. 1,942,260. The alloy Kovar is also known as Fernico. Hull and Burger in a paper[5] on glass-to-metal seals discuss seals to this alloy and many other metals), could be made to match quite closely one of the hard glasses (Corning *G*-705-*AJ*; Corning code designation for this glass is number 705) from room temperature to above the annealing range of the glass, and can, therefore, be sealed into glass in large sizes. This alloy can be rolled, drawn, and subjected to all the usual forming operations of steel. It is not attacked by mercury and consequently is one of the most important factors in the development of the "all metal" type mercury-vapor thyratrons.

For many types of structures, rather large and intricate glass pieces must be sealed to metal, for which considerable skill is required by the glass worker. It would often be far easier if a porcelain could be substituted for the main body of the glass, and then only a small amount of glass used for bonding the metal to the porcelain. The porcelain will maintain its shape to much higher temperatures

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1. For all numbered references, see list at end of paper.

than the glass and consequently only a minimum amount of skill would be required to make the joint. Seals of this type fall into the fourth class.

The desirability of such a seal has long been recognized and many attempts to obtain a satisfactory one have been made. The successful ones have all been of the "Housekeeper" type.[6] Low-expansion porcelains and glasses having approximately the same coefficient of expansion and which consequently make a stress-free seal to each other have been used. The seal has always been made to a metal of higher coefficient of expansion. In order to prevent cracking of the seal it has been necessary to thin the metal member to a very small section so that the stresses developed would be below the breaking strength of the glass and porcelain. Seals of this type are, therefore, weak where joined.

The new type of seal to be described also falls into the fourth class. The materials have been so selected and the structure so designed that it is no longer necessary to make the "Housekeeper" type seal.

General Principles

The prerequisites for making an ideal seal between metal, glass, and porcelain are:

1. Both the metal and porcelain must be wet by the glass.
2. The metal, glass, and porcelain must all have the same coefficients of expansion up to the temperature where the glass is sufficiently viscous to relieve stresses quickly.
3. All component parts must be vacuum-tight.

A satisfactory seal may be made, even though condition 2 is not exactly fulfilled. It may, therefore, be rewritten as follows: The metal, glass, and porcelain should have coefficients of expansion sufficiently alike that upon cooling after the seal is made the stresses developed due to the differences in thermal contraction are not great enough to cause a fracture of the glass or porcelain, or leave the completed seal mechanically weak.

Wetting

The bonding of glass to metal or what is known as the wetting of the metal by a glass, takes place at elevated temperatures and, in general, only when the metal is oxidized. At the elevated temperature where the glass is viscous and plastic, it dissolves some of the oxide of the metal, and thus adheres tightly to it. In order that the joint between the metal and the glass should be vacuum-tight, the oxide which forms on the metal should be a tightly adherent one. A scaly oxide would naturally give a very weak seal. Care should also be taken as to the thickness of the oxide. If the oxide is too thin, it may all be dissolved by the glass, changing the composition of the glass near the junction, and the resulting glass may not, in fact probably will not, have the same or as great a strength of bonding between itself and the metal as the original oxide of the metal exhibited. A thick oxide on the metal is likely to cause trouble also. In general, a metal and its oxide do not have the same coefficient of expansion, consequently the oxide may develop small fissures or cracks very similar to the cracks in an enameled metal surface when the enamel and metal do not match. In addition, the oxide may be of a spongy nature permitting a slow leakage of air through it.

The wetting of the porcelain by the glass takes place in much the same manner as the wetting of the metal oxide.

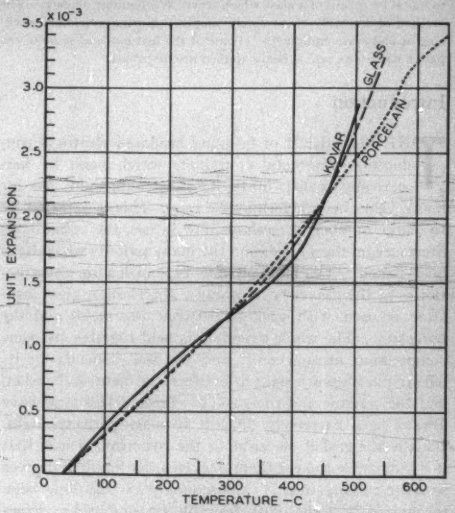

Figure 1. Expansion characteristics of component parts of metal-glass-porcelain seal

The porcelain is already an oxide material, and consequently needs no further oxidation. When the glass and porcelain are heated to a sufficient temperature they tend to diffuse into each other and form a most intimate, tenacious bond which cannot be broken free.

Thermal Expansion

The apparatus used for determining the expansion characteristics of the materials was similar to that used by Scott in his study of iron, nickel, cobalt alloys.[3,4] In order to insure a uniform temperature distribution, a special heating furnace was built which had a large copper core. Thermocouples attached along the specimen showed the maximum variation in temperature to be less than one degree.

Expansion curves were obtained for many different metals, glasses, and porcelains, but for the purpose of this paper, only one particular combination will be discussed. The materials are, the iron-cobalt-nickel-alloy, known as Kovar, the glass *G*-705-*BA* (Corning code designation for this glass is number 704), and standard electrical porcelain. As will be shown, these materials all have ap-

proximately the same expansion characteristic over a considerable range, and can be satisfactorily sealed together. Although there are other combinations of metals, glasses, and porcelains which also meet the requirements of a satisfactory seal, these particular ones have been chosen because of their availability. All components are standard materials and are readily obtainable. Figure 1 gives the total thermal expansion per unit length of the materials as a function of the temperature. They are shown together for comparison, and as may be seen they have very nearly the same average coefficient of expansion up to about 500 degrees centigrade.

Relief of Stresses

In order to show that a stress-free seal can be made between Kovar and electrical porcelain, it is necessary to show that *G*-705-*BA* glass has a low enough viscosity at a temperature around 500 degrees centigrade to permit the Kovar and porcelain members to move with respect to each other at a rate sufficient to compensate in a reasonable time for the difference in expansion between the Kovar and porcelain at temperatures above 500 degrees centigrade. If, then, all stress is relieved at around this temperature, no appreciable further stress will be developed upon cooling to room temperature, as all components contract practically the same amount.

There are two particular temperatures defined in glass technology which are of importance in connection with relief of stresses in the glass. These are known as the *anneal point*, and the *strain point*. The anneal point is that temperature at which 90 per cent of the stress in the glass will be relieved in 15 minutes. The strain point is that temperature at which the same percentage will be relieved in four hours. The range between these temperatures is usually spoken of as the annealing range. The Corning Glass Works, in published data on their commercial glasses, gives these temperatures. For *G*-705-*BA* glass they are 484 degrees centigrade and 450 degrees centigrade for the anneal point and strain point, respectively.

It would seem that, if a metal-glass-porcelain seal were made, and, before cooling, held at around 484 degrees for 15 minutes or longer, most of the stress would be relieved. That this is not true will be shown.

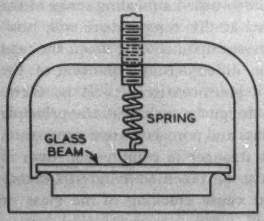

Figure 2. Glass beam loaded by means of a device having considerable elastic deformation

There are a number of methods which have been used for determining the annealing constants of glass, but only one method[7] which clearly shows the implications of these data will be described here. A small rectangular plate of the glass to be studied is supported at opposite ends, and stressed by tightening down a screw in the center between the two supports. The loading mechanism is made very rigid so that no appreciable elastic deformation will take place, and so that the glass will be permanently constrained to a fixed position. This is all set up inside a uniform temperature furnace and so arranged that light can be directed through the specimen, and relief of stresses determined directly for any particular temperature by a photoelastic method. Thus the two temperatures are found which satisfy the definition of the anneal point and strain point.

Further study has shown that these temperatures correspond to points where the glass has definite values of viscosity,[8] and that the rate of relief of stresses may be found if the viscosity is known. It was then experimentally determined that the common logarithms of the viscosity measured in poises at the anneal and strain points are 13.4 and 14.6, respectively. Since the determination of viscosity from a study of the mobility of glass fibers is a much simpler method of finding the anneal and strain points, it has almost completely supplanted the older, more direct methods. However, we must still remember that, no matter how these temperatures for rates of annealing are determined, they apply directly only to the case where the glass is constrained to some definite shape, and the stress is relieved while the glass remains in that position.

Consider a glass beam which instead of being loaded by a rigid screw is stressed through a stiff elastic spring similar to that shown in figure 2. If this is held at an elevated temperature, say the anneal point, the stress in the glass will tend to be relieved. However, as the stress in the glass is relieved, it will be still farther strained due to the elasticity of the spring. Consequently the stress in the glass cannot be completely relieved until it has deformed so far that it has permitted the elastic deformation of the spring to be completely relieved. It is at once apparent, therefore, that the annealing of a glass structure constrained by an elastically deformable means, will be greatly dependent upon the rigidity of this mechanism.

In the construction of metal-glass seals, the elastic deformation of the metal may be a very important consideration in determining the rate of relief of stress in the glass. For a simple bead seal, where a layer of glass is melted around a quite rigid metal rod, the deformation of the rod is negligible under the stresses produced. It is, therefore, substantially correct to assume that, at the annealing temperature, 90 per cent of the stresses due to any differences in expansion between the metal and the glass will be relieved in 15 minutes. It is incorrect, however, to assume that an annealing schedule which is correct for a bead on a heavy rod will be satisfactory for all other shapes of seals. Thus, for example, a bead of the same size made on a thin wall tube having the same outside diameter as the solid rod, will anneal quite differently. The initial stresses will be lower due to the fact that the metal deforms elastically, but the rate of relief of stresses will also be slower. It can be shown that after a time t the stress in the glass on the metal tube, may actually be higher than in the glass on the solid rod, even though the

initial stresses on the rod seal were higher. This is due to the fact that the rate of relief of stress is lower for the seal on the metal tube. A graphic illustration of stress versus time is shown in figure 3.

In order to have the same rate of relief of stress for the tube seal as for the rod seal, it is necessary that the viscosity of the glass should be lower. In consequence the temperature of annealing would have to be higher. It may be seen, therefore, that it is desirable to have the metal and glass match up to temperatures above the so-called annealing point of the glass.

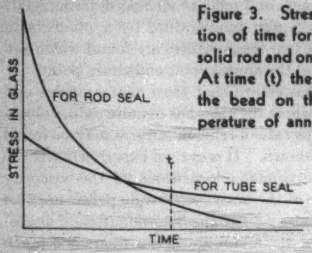

Figure 3. Stress in glass as a function of time for a bead seal on a solid rod and on a thin-walled tube. At time (t) the stress is higher in the bead on the tube. The temperature of anneal is the same for both seals

Since Kovar and *G*-705-*BA* glass match quite closely even at temperatures well above the anneal point, little difficulty is encountered in obtaining a satisfactory anneal in a short time for most any type of structure.

For a seal between Kovar, glass, and porcelain, conditions are somewhat different. Let us consider the case of a moderately thick-walled tube of Kovar sealed to a porcelain tube with a thickness a of glass between them, as shown in figure 4. The seal is made at a high temperature (usually between 900 degrees centigrade and 1,100 degrees centigrade, depending upon the design), and consequently the Kovar and glass have expanded considerably more than the porcelain. After the seal is made and cooling is started, the metal tends to contract faster than the porcelain, and consequently stresses are set up in the seal. In order that these stresses may be relieved at the lower temperature, the glass must permit the metal to move with respect to the porcelain by an amount equal to the difference in contraction between the metal and porcelain in cooling from the temperature at which the seal is made to the lower temperature. As soon as this relative motion of the parts is required during the annealing process, we see that the anneal point of the glass no longer defines the temperature at which 90 per cent of the stress will be relieved in 15 minutes. Either a higher temperature is necessary, or a longer time will be required.

Now it is known that the rate of flow with respect to each other of two surfaces in shear and separated by a viscous medium is proportional to the distance of separation (a for our case) and inversely proportional to the viscosity. Consequently the greater the thickness of the glass, the faster the relief of stresses for a given temperature.

If a seal is made using a thin layer of glass, and is cooled quite slowly, the stresses developed are so high that they usually crack the porcelain.

Figure 5 shows another way in which Kovar and porcelain might be sealed together by means of glass.

After the seal is completed and cooling started, the metal tends to shrink down on the porcelain. Now in order that the resulting stresses may be relieved, the glass must be squeezed out somewhat so that the metal can move toward the porcelain. This is analogous to a long thin strip of viscous material in compression between two plates. Doctor Nadai has shown (this is from an unpublished Westinghouse research report entitled "The Distribution of the Pressure in Thin Layers of Viscous Material Under Compression," by A. Nadai) that for this case, the velocity with which the plates move together is approximately proportional to $\frac{1}{\eta}\left(\frac{a}{l}\right)^3$ where η is the coefficient of viscosity. It is, therefore, important that the ratio l/a should not be large. For the case of the long thin strip in compression, the pressure distribution is not constant along the dimension. It has been shown that it takes on a somewhat parabolic shape, dropping very low at the edges. This is advantageous, as it tends to cut down the danger of stress concentration at the edge of the seal which might break the porcelain.

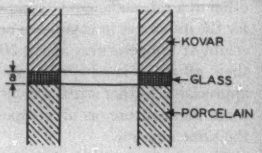

Figure 4. Kovar and porcelain sealed together by means of a thickness of glass (a)

Calculations, of the rate of relief of stress for several simple structures, have been made, but exact solutions even in the simple cases, were found quite impossible due to the complexity of the mathematics involved. The approximate solutions indicated, however, that the range of temperature, in which the greater part of the stresses developed upon cooling from a higher temperature can be relieved in a moderate length of time, is around 100 degrees centigrade higher than the so-called annealing range of the glass. Any seal annealed at this temperature will, however, develop further stresses upon cooling down the next 100 degrees, due to the difference in expansion of the components above 500 degrees centigrade. It is, therefore, necessary that the design be such that the principle residual stresses in the glass and porcelain are compression, as both are many times stronger in compression than in tension. Care should also be taken to avoid stress concentrations which might cause cracking of the glass or porcelain.

Another factor which undoubtedly enters into the relief of the stresses in seals annealed at high temperature is the relaxation in the Kovar. Scott has shown[2] that at temperatures as low as 400 degrees centigrade, Kovar loses 50 per cent of the maximum stress applied by bending, in 15 hours. At the higher temperatures, this takes place

at a much greater rate, although no specific data are available.

Any types of seal which might be made between metal, glass, and porcelain are modifications or combinations of the structures in figures 4 and 5. Consequently, from the foregoing analysis of annealing of seals, it may be seen that *it is quite impossible to obtain complete relief of stress in a metal-glass-porcelain seal in any reasonable length of time. It has also been shown that the rate of relief of stresses in metal-glass seals, and in metal-glass-porcelain seals is a function of the design constants of the structure, as well as the viscosity of the glass and relaxation characteristics of the metal.* Rough analysis and experimental verification show that by so adjusting the seal design that stress relief will continue to as low a temperature as practically feasible, a satisfactory strong seal can be made.

Vacuum Tightness of Components

Finally, in order to have a good seal it is necessary that all components of the structure, and the joints between them be vacuum-tight. Nothing further need be said about Kovar and glass, for their extensive use in the metal radio tubes, metal thyratrons, etc., speaks for them. Tests made on many types of porcelain show that all those that are well vitrified are vacuum-tight, and that a vacuum-tight seal between them and a glass of the proper expansion may easily be made. The tests were made by closing off one end of a tubular porcelain structure and sealing an ionization gauge onto the other end,

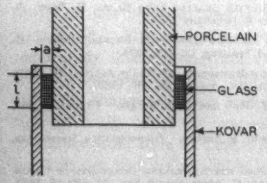

Figure 5. Kovar and porcelain sealed together by means of a thickness of glass (a) and length (l)

after which the whole structure was baked and treated under vacuum and then tipped off. Gauge readings were then taken from time to time to see if there was any leakage. No pressure change has been detected in seals made over a year and a half ago.

Tests made in a somewhat similar manner on completed metal-glass-porcelain seals show them to be vacuum-tight.

Assembly of Seals

Metal-glass-porcelain seals may be assembled in a number of ways. One of the most obvious ways is the utilization of the usual glass blowing technique. The porcelain member is brought up to temperature slowly and when it is sufficiently hot a glass bead is worked upon it at the point where the seal is to be made. The Kovar portion is then heated to a dull red heat for a few seconds to give it a slight oxidation and sealed to the glass.

For commercial production, such a method is too slow and expensive. A method is desirable by which larger quantities can be made at one time and without the assistance of skilled workmen. Such a method will now be described, as applied to the assembly of terminals for oil-filled capacitors.

Figure 6 is a photograph of the components of one of the terminals. The Kovar cap and flange, parts *A* and *E*, respectively, are drawn from sheet material, and the glass rings *B* and *D* are cut from a standard-gauge tubing. The parts are stacked together on a vertical spindle of heat-resisting steel and are ready for the furnace.

The sealing cycle depends upon the size of the porcelain pieces, and whether a batch or a conveyor type furnace is to be used. The final seal is made in the temperature range 950–1,100 degrees centigrade. If the porcelains are quite small it is sometimes possible to put them directly into the furnace at this temperature, although in general this will not be the case. Porcelain is a very poor conductor of heat, and the resulting high thermal gradient and consequent high stress is usually sufficient to crack the porcelain. Rapid heating is especially bad for the porcelain in the temperature range from about 500 to 575 degrees, where the expansion shows a marked increase. Consequently it is usually found advisable in batch assembly of small terminals to preheat, holding the furnace temperature slightly above this dangerous zone (about 600 degrees centigrade). As the porcelains come up to temperature their rate of heating becomes less and less and they are carried through the dangerous zone without cracking.

Above this temperature the expansion coefficient is lower, and the porcelain will stand higher thermal gradients. The assembly may, therefore, be transferred directly from the preheat furnace to the sealing furnace, which is at a temperature of around 1,100 degrees centigrade. Except for very small terminals which can be

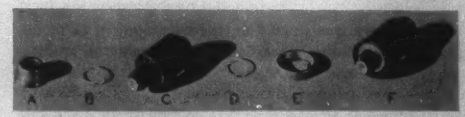

Figure 6. Component parts of a metal-glass-porcelain terminal seal and a completed terminal

A—Kovar cap B and D—Glass rings C—Porcelain
E—Kovar flange F—Completed terminal

heated rapidly it is usually desirable to have the sealing operation take place in an oxygen-poor atmosphere in order to prevent overoxidation of the Kovar. An atmosphere of tank nitrogen is satisfactory.

After the seal is made the terminal should again be brought to an intermediate temperature furnace at around 600 degrees centigrade. It is during the interval of cooling to this temperature, and while at this temperature, that the major portion of the annealing takes place.

Figure 7. Inerteen-filled capacitor using two metal-glass-porcelain terminals

It also may be desirable to maintain a hydrogen atmosphere in this furnace in order to reduce the surface oxides on the exposed Kovar surfaces.

The terminals are next moved to a cooler zone in the furnace and after they reach a temperature around 300 degrees centigrade where no appreciable oxidation of the Kovar will take place, may be removed from the furnace.

It has been found possible to use the same furnace for both the preheating and for the cooling and annealing.

Figure 6*F* is a completed terminal which was assembled using the following cycle: seven minutes, preheating; 15 minutes, sealing; and 20 minutes, cooling and annealing. The correct cycle to be used is largely a matter of size and shape of the porcelain and may best be determined by experiment. If the quantity is sufficient to warrant it, a seal of this type is admirably suited to production in a continuous-type furnace.

Applications

When work was started on the development of metal-glass-porcelain seals, it was intended primarily for application to vacuum-type equipment. It soon became apparent, however, that the demand for oil-tight and gas- and vapor-tight terminals was greater, as the needs of those using vacuum containers were quite well met by metal-glass seals. It is in consequence of the relative demand, that the first designs of the metal-glass-porcelain seal were for use on oil-filled capacitors.

Figure 7 shows an Inerteen-filled capacitor using two metal-glass-porcelain terminals of the type just described. The terminals are soldered into the can and the leads from the capacitor brought out through the opening in the caps. These are soldered to the caps at the same time the threaded studs are soldered in. Terminals for capacitors are standard in three different sizes, and others are being used experimentally. The same terminals are being considered for other applications such as small oil-filled transformers, and oil-filled portable X-ray equipment. They have a distinct advantage over other types, in that they permit bringing the leads out of the container below the oil level.

The possible uses of a seal of this type are so many and varied that it would be impossible for me to enumerate them. In fact, it may be used practically any place where an electrical lead into a hermetically-sealed container is desired. The individual reader will undoubtedly be able to select from his own experience many places where it might be applied.

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A Stabilized Amplifier for Measurement Purposes

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Synopsis: This paper describes a stabilized amplifier with an over-all amplification ratio that remains essentially constant in magnitude and phase for all changes in tube characteristics, line-voltage variations, and output load variations to be expected during normal operation. This stability is obtained by the introduction of two stabilizing circuits which act independently, yet are complementary when used together. During a period of eight weeks' use two such amplifiers with their associated indicating instruments maintained their original calibration within two-tenths per cent of full scale without readjustment.

Introduction

DUE TO ADVANCES in electron tubes and amplifier technique electronic devices have found a rapidly expanding field of application. They have been used quite extensively in measurements and with the aid of amplifiers[1] it is possible to measure smaller quantities than ever before. Such quantities as voltage, current, time, sound, light, and distance can be measured and, moreover, the measurement can be made without appreciably disturbing the circuit characteristics by the introduction of the measuring device.

However, past experience has indicated that when an ordinary amplifier is used to extend the sensitivity of an indicating instrument, such as a voltmeter or ammeter, the accuracy, reliability, and ease of operation of the amplifier do not begin to approach those of the indicating instrument. Although the electron-tube amplifier has remarkably linear properties, variations in tube characteristics between different tubes, with the age of tubes, and with changes in plate voltage and cathode temperature ordinarily cause the over-all amplifier characteristics to change from time to time. Accuracies in the order of one-half per cent are available in present-day instruments and if the over-all amplifier characteristics are not to extend this limit it is necessary either to control the variables during operation or else provide means for a special calibration to check each reading. Either method is inconvenient from the operator's viewpoint and in many cases the resulting uncertainty in measurement does not permit the use of such an amplifier. Either special instruments are built or special ways of using instruments are devised.

In such applications where accuracy and reliability are important, together with sensitivity, it is desirable to have an amplifier whose characteristics are essentially independent of the aforementioned variables.

Specifications

One of the major problems encountered during the recent design of a 480-cycle network analyzer[2] was the measurement and instrument system. A network analyzer consists essentially of a large number of variable circuit parameters conveniently arranged for interconnection such that various circuit problems which are too complicated or involved for direct mathematical calculation may be set up in miniature and the actual results measured by trial (volts, amperes, watts, phase angle, etc.). Such analyzers are used primarily in making load and stability studies of power systems, but the circuits are flexible enough so they can be used for a great variety of problems.

For such an analyzer it is desirable to have instruments that are: easy to read without undue eye strain up to distances of several feet, rapid in response, able to withstand overloads and abuse, easy to use, and accurate to one-half per cent with direct-reading scales. Now these requirements alone would not preclude the direct use of indicating instruments, but it is also necessary to reduce the disturbance caused by inserting the instruments into the network to a point where it can practically always be neglected even when the network is lightly loaded. In an effort to reduce the size, weight, and cost of this analyzer, the power consumption of the total network is made small. Thus, the allowable instrument power consumption is reduced to such a small value that it is hopeless to attempt to use directly any kind of an indicating instrument even if some of the other desirable characteristics are sacrificed. For instance, it is desirable to have an ammeter voltage drop that is not in excess of 0.010 volt with various full-scale currents of 0.010–0.050–0.250–1.000 ampere. The voltmeter should not require over 0.000150 ampere (150 microamperes) when measuring full-scale voltages of 15–30–75–150 volts. Having given these specifications for sensitivity, the primary considerations are accuracy and reliability.

In the network-analyzer application current is measured by inserting a low-resistance shunt into the circuit and then amplifying the voltage drop across this shunt. The amplifier input impedance in parallel with this resistance is made high enough so it may be neglected. For instance, the current amplifier input impedance is not less than 5,000 ohms (maximum resistance of shunts is one ohm) and with the full-scale voltage drop of 0.010 volt the amplifier input is some 0.000002 ampere (two microamperes). This input corresponds to an amplifier output of 0.100 ampere so the current amplification is about 50,000.

Voltage is measured by using a tapped high-resistance voltage divider, each tap having sufficient resistance to

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1. For all numbered references, see list at end of paper.

limit the current to 0.000150 ampere at the desired full-scale voltage. The voltage drop across a 3,000-ohm portion of the divider is amplified for an indication. The amplifier input impedance is not less than one megohm, which at full scale requires about 0.00000045 ampere (0.45 microampere). This input corresponds to an amplifier output of 0.050 ampere, the over-all current amplification being about 100,000. However, while the actual amplifier input is in the order of 0.1 microvolt-ampere; the relative disturbance caused in any circuit by the introduction of these amplifiers for making measurements must be measured by the over-all volt-ampere requirements of the complete unit and not the amplifiers alone. In this case, the volt-ampere requirement of the resistance shunt is predominant. A current of 0.010 ampere is measured with 0.010-volt drop and a voltage of about 0.5 volt can be measured with a current of 0.00015 ampere; about 0.0001 volt-ampere (100 microvolt-amperes) being required for full scale in each case.

To get a better conception of the meaning of these figures consider table I and compare the volt-ampere requirements of those high-quality a-c instruments in common use with that required in the network-analyzer instruments. The instrument voltage and current ratings given were chosen as typical values that might be expected of an average quality portable instrument in general use. The ammeter voltage drops were derived from the instrument impedance and current ratings and the voltmeter current requirements were derived from the impedance and voltage ratings. The volt-ampere requirements give an approximate idea of the relative disturbance caused when that type of an instrument is introduced into a circuit. To further facilitate this comparison a column is included in which the volt-ampere requirements are expressed in relative values considering the new ammeter value as unity. For convenience in comparison the wattmeter potential- and current-element volt-amperes are added together.

Of those instruments listed the electrodynamic and the moving iron are probably in greatest general use because of their high accuracy and reliability, but note that they require the largest volt-ampere input for operation. Also, due to the increase in reactance drop at higher frequencies, the volt-ampere requirements and errors increase quite materially. Particularly does the wattmeter accuracy suffer at higher frequencies because of various phase shifts and mutual effects in the windings. This is especially important in this application because the wattmeter must maintain its accuracy even at very low power factors; a requirement exceedingly difficult to obtain even at 60 cycles. So these volt-ampere requirements tell but a small part of the difficulties encountered in building a wattmeter. A conventional thermocouple instrument is useful even at very high frequencies but is extremely slow in response and quite easily burned out with overloads. Descriptions of thermocouple wattmeters have been published but such wattmeters are not in general use. The accuracy of the rectifier type of instrument is not high enough for this application and the wattmeter is not commercially available.

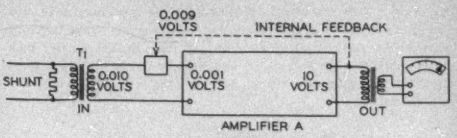

Figure 1. Internal feed-back circuit

Table I. Volt-Ampere Requirements at 480 Cycles of Representative 60-Cycle Instruments Compared With New Amplifier Type

Instrument	Characteristics at 480 Cycles			Ratio to Amplifier Type
	Volts	Amperes	Volt-Amperes	
Ammeter				
Electrodynamic	2	.5	10	100,000
Moving Iron	1	.5	5	50,000
Thermocouple	0.25	0.05	0.012	120
Rectifier	2	0.01	0.02	250
Amplifier	0.01	0.01	0.0001	1
Voltmeter				
Electrodynamic	150	0.07	10	100,000
Thermocouple	1	0.001	0.001	10
Rectifier	1	0.0005	0.0005	5
Amplifier	0.7	0.00015	0.0001	1
Wattmeter*				
Electrodynamic				
Current	1.5	.5	7.5	
Potential	100	0.02	2	
			9.5	95,000
Amplifier				
Current	0.01	0.01	0.0001	
Potential	0.7	0.00015	0.0001	
			0.0002	2

* Volt-amperes of potential and current elements combined for convenience.

So, after giving due consideration to the various instrument characteristics, it is apparent that to satisfy the requirements of speed, accuracy, reliability, low burden, etc., it is advisable to use the electrodynamic or moving-iron type of instrument either of which is suitable on every score except sensitivity, and then supply this sensitivity with an amplifier. Of course, the amplifier must be as reliable in every way as a high-quality indicating instrument. The input-output ratio and phase angle must remain constant within one-half per cent for all changes in tube characteristics, plate voltages, etc., to be expected during operation. Also, as it has turned out, the amplifiers must be able to correct some of the inherent inaccuracies found in a moving-coil-type wattmeter.

Description

The over-all amplifier input-output ratio is made essentially independent of most changes that occur within the amplifier by introducing two stabilizing feedbacks. Each acts independently yet they have a compounding effect when used simultaneously. The specific amplifier referred to in the text is designed only for a frequency of 480 cycles (±2 per cent); however, with suitable modifi-

cations the feed-back principles described can be applied to other single-frequency or broad-band amplifiers.

In the first stabilizing scheme, an internal feedback similar to that used by H. S. Black[3] and associates, the amplifier is deliberately built with several times the necessary amplification, and then, by feeding a portion of the output back on the input in such a way as to throw away the excess amplification, the amplifier will acquire new

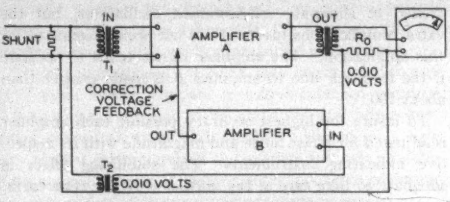

Figure 2. Null-balance feed-back circuit

properties, the most important of which is constancy of amplification and freedom from nonlinearity.

The principle of such an amplifier can be explained quite readily by considering a specific example. Assume, as shown in figure 1, that 0.010 volt is available as amplifier input to give a ten-volt output. A represents an amplifier that delivers ten volts output with 0.001-volt input, but instead of using it as an ordinary amplifier part of the output voltage, namely, 0.009 volt, is introduced back into the input circuit such that the amplifier input of 0.001 volt represents the difference between the feed-back voltage of 0.009 volt and the impressed voltage of 0.010 volt. Amplifiers are subject to normal variations in the order of ten per cent so assume that for some reason or other the amplifier in question should change and now require an input of 0.0011 volt instead of 0.0010 volt, an increase of ten per cent. The output voltage remaining constant, the feed-back voltage will be 0.009 volt. Adding to this the new amplifier input of 0.0011 volt, the total input required is now 0.0101 volt instead of 0.010 volt as before. This represents an increase of one per cent in input volts corresponding to an error of ten per cent in the amplifier ratio, so with a feedback of ten times, the errors are reduced to one-tenth. By increasing the amplification and increasing the feedback, the error can be reduced still further, until a point is reached where the feedback is so large that the over-all amplification characteristics are substantially unaffected by most changes in the amplifier. It is far from a simple proposition to employ feedback this way because of the tendency for oscillation and the very special control which is required of phase shifts in the amplifier and feed-back circuits over a wide range of frequencies above and below the useful frequency band. However, once having achieved a design in which proper phase relations are secured the performance obtained is perfectly reliable.

When adjusted properly this scheme exerts a remarkably stabilizing effect on the amplifier but a second means for obtaining stability is used which serves as a check on the first. This second means consists of an external feedback, which is so-called because it is external to amplifier A and which is nothing more or less than a special use of the familiar and extremely accurate null-balance system. As shown in figure 2, a resistance R_0 is introduced in the output circuit of such value that 0.010 volt appears across it with the proper full-scale current flowing through the indicating instrument. This voltage is then compared with the input voltage of 0.010 volt and they should be identical. However, should either one increase or decrease more than the other or change phase angle with respect to the other there will be a voltage difference. This difference, or error as it is in this case, can then be amplified by an amplifier such as B and introduced directly back into amplifier A in such manner that it will adjust the output of A to the correct value corresponding to the input voltage.

There is another advantage in the use of this circuit that might not be evident at first glance. The secondary of transformer T_1 (figure 2) is supplying power to the grid of the first tube in amplifier A. This power is small to be sure, but due to the internal grid-to-cathode capacitance of the tube, there is sufficient leading current to cause a slight phase shift in the output of transformer T_1. This introduces an error which is not corrected by use of the first feed-back system alone. The secondary of transformer T_2 feeds into the grid of the first tube of amplifier B, but its voltage output is balanced against the voltage across R_0, so the only current that can flow in this transformer and cause phase shift will be due to the difference between these two voltages. Normally this difference will be very small and, therefore, the secondary of T_2 will be essentially open-circuited and its secondary voltage will be truly representative of the voltage drop across the shunt regardless of variations in tube grid characteristics, and can be balanced against that portion of the output voltage appearing across R_0 for a true comparison of the input and output of amplifier A.

Obviously the effectiveness of this method depends on how much the output voltage must depart from its cor-

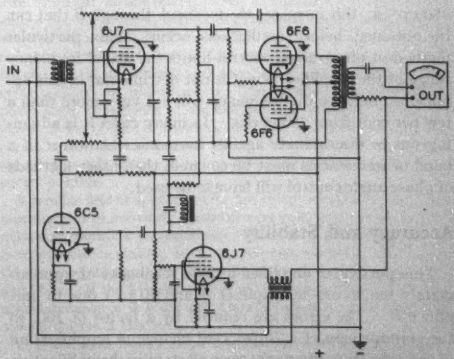

Figure 3. Electrical circuit of stabilized amplifier

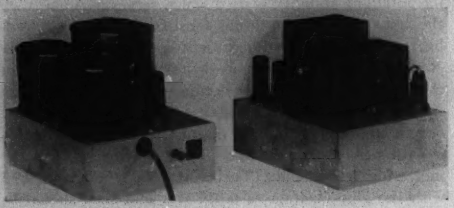

Figure 4. Stabilized amplifier and associated power-supply unit for General Electric 480-cycle a-c network analyzer

rect magnitude and phase to produce the necessary corrective effect. The smaller this voltage the more accurate the balance; the limiting condition being when self-sustained oscillations occur.

The complete amplifier circuit incorporating both systems of feedback is shown in figure 3. The main amplifier consists of a pentode driving a power pentode with a second power pentode connected to the output transformer in such manner as to cancel the d-c flux in the output-transformer core. The internal feedback is made from the plate of the output pentode through a resistance voltage divider to the cathode of the input tube. This connection is necessary to secure proper phasing. The output circuit is tuned with a series capacitor to bring the current in proper phase with the input voltage. The null-balance amplifier consists of a pentode driving a triode with a voltage divider in the triode output to allow control of the correction voltage introduced into the main amplifier. The input pentodes are used because of their low input capacity together with their high amplification and the triode is used in the null-balance amplifier to keep the resistance value of the voltage divider as small as is practicable. Commercially available parts are used throughout. A photograph of the amplifier and associated power supply is shown in figure 4.

The amplifier circuit constants are quite conventional. The plate circuit of one stage of amplifier B is tuned at 480 cycles; this increases the feedback through B that can be obtained before oscillations occur. This particular method of phase-angle control limits the useful frequency range of the amplifier, but it is not detrimental in this application because the frequency will not vary more than a few per cent from 480 cycles. In many cases it is advantageous to discriminate against harmonics; however, if a band of frequencies must be covered, then other methods of phase angle control will have to be used.

Accuracy and Stability

This particular amplifier utilizes feedbacks of approximately ten to one in amplifier A and 70 to 1 due to amplifier B. The errors are reduced by a factor of 700, so the extreme case of a 70 per cent change in amplification of one tube only affects the over-all stabilized amplification by one-tenth per cent. The stabilizing effect is so great that the over-all amplification characteristics are substantially unaffected by changes in the amplifier.

It would be possible to increase the feedback in amplifier A to many times the above value,[3] but in this particular application the extra stability was not necessary and the simplicity of a two-stage amplifier seemed advantageous. Likewise, the effectiveness of the feedback due to amplifier B can be increased providing that the various phase shifts occurring in amplifiers A and B can be controlled to eliminate self-sustained oscillations, but the extra complications involved did not seem warranted for this application. The amplifier shown tends to oscillate if the feedback due to amplifier B is made greater than about 100.

To insure the highest accuracy possible each amplifier is adjusted for phase angle and magnitude with its respective indicating instruments. The stabilizing effect is adequate to take care of the normal ± 10 per cent variation in instrument reactance between zero and full scale.

The input-output ratio can be maintained so precisely by using these two stabilizing systems that ordinary instruments are not accurate enough to use in obtaining the initial adjustments. By virtue of the null-balance circuit the input to the null-balance amplifier represents any over-all error in magnitude or phase angle between the input and output, so the initial adjustments are made until the output of this amplifier is zero. The ratio of amplifier A is controlled by varying the amount of internal feedback and the phase angle of the output current is adjusted to compensate for the inductance of the indicating instrument by means of a series capacitor.

An indicating device can be connected to the output of the null-balance amplifier and used as an indicator to show if the amplifier is working properly. In the network analyzer application this was not thought to be necessary because a circuit is provided, to which the amplifiers may be connected, and in which the voltage and current are adjusted to give predetermined deflections on the voltmeter, ammeter, and wattmeter. By connecting both amplifiers to this "standard circuit" they can be checked one against the other. This is not used as an absolute calibration for the instrument system but it does serve to increase the reliability for, if the readings do not check, something must be wrong with one or both measuring circuits.

Several of these amplifiers have been made and calibration tests indicate an accuracy of better than one-tenth per cent in magnitude and ten minutes in phase angle. The amplifiers are rated one-half per cent and 20 minutes. Tubes can be interchanged freely, and line-voltage variations on the amplifier power supply of 20 per cent do not change the calibration; however, when using high-speed light-beam instruments, severe transients in the 60-cycle power supply will cause the light beams to jump, after which the reading returns to the correct value. To eliminate this, a regulator can be placed in the 60-cycle supply to the amplifier power units to remove these transients. After being in constant use for eight weeks, two amplifiers and their associated indicating instruments were found to have a maximum deviation from their original calibration

of two-tenths per cent of full scale without any readjustment.

Conclusion

With the proper use of stabilizing circuits, electron-tube amplifiers can now be built that are just as accurate and reliable as, and in many respects better than, the indicating instruments with which they are to be used. Such amplifiers combine the characteristic low power-input requirements of vacuum tubes with the accuracy and reliability found in high quality measuring instruments.

The use of stabilized amplifiers may be extended to any application where accurate measurements are required of quantities too small to be measured any other way. Their proved accuracy and reliability should go a long way toward getting around the average engineer's inhibitions against the use of electron tube apparatus whenever accurate and reliable measurements must be made.

References

1. Amplifiers for A-C Bridges, Ford and Bousman. *G. E. Review*, May 1934, page 224.

2. A New Alternating Current Network Analyzer, H. P. Kuehni and R. G. Lorraine. AIEE technical paper number 37-182.

3. Stabilized Feedback Amplifiers, H. S. Black. Electrical Engineering, January 1934, volume 53.

Discussion

H. L. Hazen (Massachusetts Institute of Technology, Cambridge): This paper, in my opinion, describes a significant development in the field of electrical measuring instruments. By the technique here described it is practicable to attain a new order of speed of response and accuracy in rugged, low-burden instruments. It appears that the possibilities of this technique are numerous where the accuracy and speed of standard portable instruments are desired with burdens that are a minute fraction of those imposed by such portable instruments themselves.

Apart from the significance and utility of the design as a whole, there are several questions regarding the details on which I should like to comment in this discussion. There are two types of feedback employed in this amplifier which for the most part are mutually helpful. One of these feedbacks—the linear feedback—is actuated by the output voltage. The other—that due to amplifier B—is actuated by output current. It appears that in a device of this sort, in which the indicating instrument inherently responds to current rather than to voltage, the amplifier should be so designed as to maintain the desired mutual conductance of the unit as a whole. That is, for any given input voltage a definite current proportional to this voltage is desired in the indicating instrument. It appears that feedback based entirely on output current rather than on voltage or a combination of voltage and current, is therefore desirable.

A theoretical analysis of this amplifier has been made with Mr. G. S. Brown to determine the effects of these feedbacks and to compare them with other feed-back schemes. One basis of comparison is the ratio of the fractional change in mutual conductance to the fractional change in another variable, such as the gain of amplifier A, the impedance of the output circuit, or the internal impedance of amplifier A as viewed from its output terminals. With the scheme as used, it appears that the fractional change in the mutual conductance is about one seven-hundredths of the fractional change occurring either in the gain of amplifier A or in its internal impedance as viewed from its output terminals. In contrast, the fractional change in the mutual conductance is not one seven-hundredths, but one-seventieth of the fractional change in the load impedance because the linear component of feedback is based on output voltage rather than output current. If a comparable amplifier is made in which the feedback is all based on output current, the change in the mutual conductance caused by changes in amplifier-A voltage ratio, by changes in amplifier-A impedance as viewed from its output terminals, or by changes in the load impedance—all become the same. It appears, therefore, that for a device of this sort, feedback based on output current rather than on output voltage is desirable.

It is stated in the paper that one advantage of using the type of feedback involving amplifier B is that it tends to make the voltage actually applied to the input terminals of amplifier A approach zero, and therefore reduces the current drawn at the input terminals of this amplifier. This statement seems open to discussion on two counts: First, it can be seen that if amplifier A and its linear component of feedback are suitably adjusted, the input to amplifier B is zero, and its output voltage is therefore necessarily zero. Hence it appears that amplifier B does not have any effect on the magnitude of the amplifier-A input voltage unless amplifier A and its linear component of feedback are out of adjustment.

Second, any degenerative feed-back scheme—linear or otherwise—serves the purpose attributed to amplifier B, namely, it puts a voltage in series with the signal input voltage which has such polarity and magnitude as to make the sum of these voltages small compared with either. Thus, assuming the amplifier-B scheme of feedback to be functioning, it does nothing that any other feed-back scheme would not do on this count.

Another way of considering the relative magnitudes of signal voltage and actual amplifier input voltage is this: For a given amplifier output and amplifier gain, the input voltage to the amplifier is fixed. If the amplifier mutual conductance is N times the desired ratio between output current and actual signal voltage, then the net amplifier input voltage is necessarily only $1/N$ of the signal voltage. This, as was pointed out above, is characteristic of any degenerative feed-back amplifier and not merely of the particular type of feedback represented by amplifier B in this circuit.

In raising the foregoing questions I do not wish to detract in any way from the value of this development. On the contrary, the contribution seems so significant in the measurement field that it is worth while to give attention to matters which may be relevant to the design of similar units in the future. The foregoing comments are based primarily on theoretical considerations, and I shall be glad to have the author's comments, both from the theoretical and from the practical point of view.

F. K. McCune (General Electric Company, Lynn, Mass.): Mr. Thompson's paper should be of universal interest to those concerned with electrical measurements. The combination of circuits described appeals to me as particularly ingenious since it compensates not only for magnitude of current but for phase angle as well. I feel that this latter feature is deserving of special comment since the accuracy of correction is such as to be perfectly adequate for the great majority of measurements. The value of ten minutes of phase angle corresponds to one-half per cent at 50 per cent power factor, however, and is therefore too large to neglect for very accurate measurements of power or vars. It will be of interest to see whether the continued use of these circuits shows greater accuracy possible.

A possible field of application for this circuit would seem to be the measurement of extremely small currents such as are dealt with in noise and vibration measurements. Here the effect of "pick up" from extraneous sources, both of noise and vibration, may affect the readings obtained, due to the disturbances they produce in the amplifiers. If the frequency range of the circuits described can be made large enough, it would offer a possible solution to many troublesome problems of this sort.

It would seem from a rough examination that while phase-angle errors in A would be corrected by B, that phase-angle errors in B would result in considerable errors. For example assume currents

in the shunt and in R_s initially ten minutes out of phase. If amplifier B should have a ten-minute phase angle and the result should be subtractive, an out-of-phase current with a magnitude of a fraction of one per cent would be impressed on B and would be there amplified and impressed on A exactly in phase. The result would be no improvement in phase angle and an increased error in magnitude.

Probably this is only a theoretical possibility, but calibration data on the circuits will, no doubt, be taken periodically and will give the real answer to all such considerations.

M. S. Mead (General Electric Company, Schenectady, N. Y.): In the discussions of Mr. Thompson's paper, "Stabilized Amplifiers for Network Analyzer," there appear to be four points which should be answered. Mr. McCune mentioned that in a wattmeter, even a very small phase-angle error will result at low power factor in considerable error. This is a well-recognized difficulty in all wattmeters and in this case the answer simply is that extreme accuracy in power or var measurements at low power factor is not required. So far, in the operation of the board, the accuracy of the watt and var measurements has been great enough, even at low power factors, so as not to handicap the operation of the board in any way.

The second point he raised was in connection with the effect of phase-angle error in amplifier B on the phase-angle error of amplifier A. Without taking the time to submit a proof, it may be stated that with large amounts of feedback, any small departure from 180-degree feedback will result in an infinitesimal reduction in the benefits secured from the feedback. Therefore, we conclude that a small phase-angle error in amplifier B is unimportant.

I know that Mr. Thompson appreciates the nice things Prof. Hazen said about the development. In his discussion, Prof. Hazen mentioned two things. He stated that it would have been better to have designed the amplifier so that 700 times current feedback was used alone without the voltage feedback. Others have offered the same comment. We are in entire agreement with this thought. However, it is extremely difficult to build an amplifier including an output transformer and having a feedback ratio of 700. Confronted by limitations of time and facilities, nevertheless, a feed-back ratio of 700 was secured by using the compound effect of two separate feedbacks, each of which was quite easy to get.

The second point Professor Hazen mentions apparently resulted from some misinterpretation of the text. The paper stated that there was a distinct benefit secured from using external feedback and a reference voltage derived by an additional transformer across the current shunt. This advantage is not concerned with the amount of grid voltage input to amplifier A as Professor Hazen understood was claimed, but rather to amplifier B whose input voltage approaches zero and consequently the amplifier cannot act in any manner as a load on the transformer supplying the reference voltage.

H. A. Thompson: The discussion seems to center around the question of just which feedback is the simplest and best. Considering that the particular instruments used respond to current rather than voltage, as Professor Hazen has mentioned, it is advantageous to use current feedback and control the transconductance of the amplifier rather than the voltage amplification.

The time at our disposal to develop this amplifier was limited and a conservatively rated two-stage amplifier with feedback appeared to be the simplest and most reliable unit we could assemble and still get the required amplification. The null-balance amplifier B was added to serve as a check on the performance of amplifier A and also to compensate for the variation in instrument inductance and the mutual voltages introduced in the wattmeter coils. No trouble was experienced due to the effects of phase shifts in B. If necessary, it would have been a simple matter to stabilize B with negative voltage feedback similar to that used in A. As a matter of fact, tests indicated that the tuned circuit used in amplifier B could be detuned considerably without any harmful effects.

Doubtless, if the time and money were available, this amplifier could be improved, but for this particular application the accuracy and reliability needed did not warrant any further development. Operating experience has indicated that the amplifiers perform well within the operating requirements of the network analyzer. In fact, the wattmeter has been used at power factors as low as seven per cent with acceptable accuracy, and phase angle measurements are made using the wattmeter at zero power factor.

Phanotron Rectifiers as a D-C Supply for Elevator Motors

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Introduction

THERE ARE a number of public utilities that have instituted programs for curtailing and in some cases completely eliminating the d-c power supply to concentrated load areas. The change from d-c to a-c power supply for elevators in the affected areas requires the substitution of a-c elevator equipment or the use of converters to supply d-c to the existing elevator equipment. Elevators may be operated equally well from either alternating current or direct current, so the choice is dependent upon the cost of the change-over.

Where a converter is to be used, a phanotron rectifier possesses many advantages. Its first cost is competitive with other forms of converters. It has no rotating parts and so requires no special foundations, and it is quiet in operation. These two characteristics permit greater freedom in selecting the location of the converter. It is more efficient than a motor generator set. It is semi-automatic in operation, thus requiring little attention from the building attendant.

The phanotron rectifier used for elevator power supply is of particular interest as it is the first industrial application of the modern type of metal electron tube in power sizes. In addition the automatic features incorporated in these rectifiers have resulted in a very successful service record and consequently merit the careful attention of those interested in applying electronic equipment for power purposes.

Before describing the phanotron rectifier and considering its features, the power requirements of elevators will be reviewed.

Power Requirements of Elevator

Elevators with few exceptions are simple counterweighted hoists in which counter weight generally equals that of the cab and its appurtenances, plus 40 per cent of the cab capacity. The motor load is characterized by peak power consumption during the starting and accelerating period followed by a very much reduced load during the running period, which depends upon the number of passengers in the cab, and may be regenerative in character, followed by regenerative braking to a slow speed or stop. The current required to accelerate full load may vary from 100 to 250 per cent of the current required to hoist full load. The usual maximum regenerative load on gearless installations is approximately 48 per cent of that required to hoist full load, and on geared installations, 23 per cent.

Where there is more than one elevator in an installation, it is impossible to predict the load demand from the speed and capacity of the various elevators. The average elevator does not operate more than 50 per cent of the time that it is in service. Since the loading is usually directional with respect to time of day, maximum load will not be required more than 25 per cent of the operating time. Consequently, the ratio of maximum to average load will be high where only a few elevators are involved in a given plant. As the number of elevators increases, the ratio reduces and the short time power peaks become less pronounced. The type of motor used also has a considerable effect on the shape of the power demand curve. A typical elevator load is shown in figure 1.

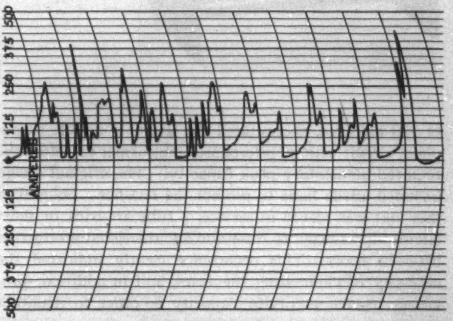

Figure 1. Typical load on a bank of three elevators with 35-horsepower motors

If load curves can be obtained during times when the elevators carry heaviest loads, the maximum momentary peak current, the average current, and the root mean square current may be estimated and used as a basis for determining the size of the phanotron converter.

The First Installation

In the fall of 1935, a trial installation was made in Chicago using a four-tube rectifier operating from a power supply of 208 volts, 3 phase, 60 cycles, and delivering direct current at 230 volts. Operating data obtained before the change-over showed instantaneous peaks in excess of 200 amperes. These peaks and the fact that the only phanotron tube in this current range was rated 30 amperes average with a momentary peak commutating capacity

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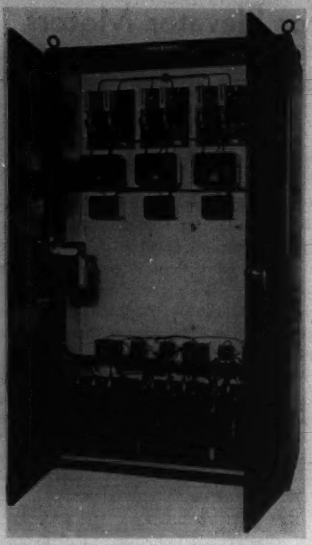


Figure 2A. Front view of rectifier with doors open

of 150 amperes, necessitated the use of a double single-phase circuit with an interphase transformer to obtain the required momentary peak capacity. The original design included anode fuses to protect the rectifier. Soon after this unit was placed in service, a tube arc-back or short circuit blew the anode fuses and left the elevator stranded between floors. This occurrence clearly indicated the necessity of eliminating the fuses, and in addition, providing reserve rectifying capacity in order to maintain service in event of a tube failure.

Phanotron Rectifier

A modified rectifier design using six phanotron tubes, anode contactors, thermal overload relays, and reclosing timers was then built. It operated so successfully that all subsequent rectifiers for elevator service have followed this same fundamental design.

The general appearance of the rectifiers is shown in figure 2. It consists primarily of phanotron tubes mounted in the middle section, with power transformers and interphase transformers mounted in the base. The associated control and protective equipment is mounted upon a panel within the cubicle, and the cubicle is provided with two full length hinged doors to give ready access to all parts of the rectifier. The tubes are enclosed in an individual section at the back of the cubicle, which extends the length of the rectifier, access being provided by two small hinged doors inside the enclosure. This compartment is in effect a chimney providing the proper ventilation to maintain the tubes at the desired operating temperature. The screened opening through which the ventilating air enters is located at the rear of the cubicle.

To date, there have been built seven 230-volt units and three 550-volt units. These range from 25 kw for one hour to 40 kw continuously at 230 volts, and 50 kw for one hour at 550 volts.

These rectifiers are usually described by a one-hour kilowatt and a peak-current rating as the elevator load is directional and highly concentrated with respect to time of day.

Phanotron Tubes

The phanotron tube used in the elevator type of rectifier is of the directly heated hot-cathode type, with a metal envelope, internal insulated anode, and mercury vapor. The tube (This tube bears the trade designation *FG*-166.), figure 3, is designed to operate at condensed mercury temperatures of from 20–80 degrees centigrade. This range corresponds to an ambient temperature of from 20 degrees to 50 degrees centigrade. Before a rectifier of this type can be placed in service, the proper vapor conditions must be established inside the tubes and the filaments must be brought to the emitting temperature. To accomplish this, the filaments should be energized for a short period of time, one to two minutes under ordinary conditions or a longer time if low ambients are encountered. If the rectifier is to be placed in a position where the ambient goes below five centigrade, thermostatically controlled dampers or louvers are used in the ventilating system to assist in maintaining the proper operating temperature of the tubes.

The average expected life of this type of tube is 10,000 hours when operated under conditions described here. Four installed in October 1935 have already given approxi-

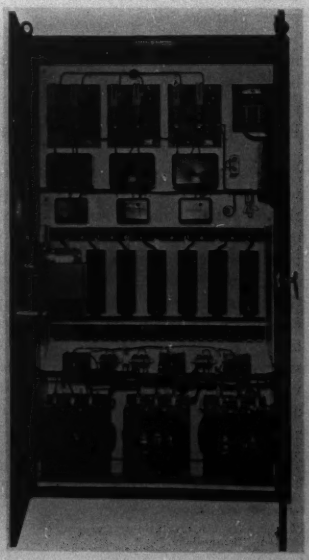


Figure 2B. Front view of rectifier with main door and tube-compartment door open

mately 16,000 hours service and twelve installed in January 1936 have been operating continuously with no failures.

Triple Single-Phase Full-Wave Circuit

In a single-phase full-wave connection, each tube carries current for 180 electrical degrees. The tube used in the rectifiers has an average rating of 30 amperes with a peak rating of 150 amperes. Thus, such a single full-wave rectifier would have an average current rating of 60 amperes and a maximum momentary peak rating of 150 amperes. Likewise, three such rectifiers, one connected to each phase of a three-phase supply, and having their cathodes paralleled through interphase transformers, would have a combined rating of 180 amperes, and a momentary peak rating of 450 amperes. This arrangement of connections will be called a triple single-phase circuit. The triple single-phase full-wave circuit has the additional advantage of balancing the load on the three-phase supply. Also this arrangement increases the ripple frequency and reduces its magnitude because of the 120-degree displacement resulting in a smoother d-c voltage. Considering motor generator sets, however, I would say that the set had a continuous rating of 180 amperes and a maximum commutating peak capacity of 450 amperes which the generator could safely produce. The single-phase circuit makes possible the maximum utilization of the current carrying capacity of the tube resulting in greater reliability of operation and longer tube life than is obtainable in any other type of circuit so far available for intermittent service.

The experience gained on the four-tube rectifier indicated the desirability of using a circuit which would have enough reserve capacity to keep the elevators in service in the event of a tube failure. The triple single-phase full-wave circuit accomplishes this purpose as it may be operated as a double single-phase full-wave circuit and produce two-thirds of its rated output simply by opening the circuit having a faulty tube as an inspection of the elementary circuits will show this possibility.

The power and control circuits are shown on figure 4, elementary a-c control diagram; figure 5, elementary diagram of power circuit; figure 6, elementary d-c control diagram.

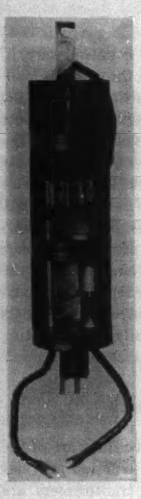
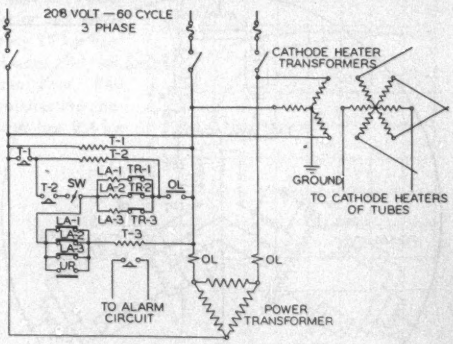


Figure 3 (left). FG-166 hot-cathode tube used in rectifiers

Figure 4 (right). Elementary a-c control diagram

T-1—Cathode-heater timing relay
T-2—Reclosing timing relay
T-3—Alarm relay circuit
LA1, 2, 3—Thermal relays
TR1, 2, 3—Thermal relays
OL—Overload relay
SW—Control switch
UR—Unbalance relay



Functions of Semiautomatic Control

In case a tube arcs back, the a-c overload relay (*OL*) opens the coil circuit to the anode contactors which immediately open. After two seconds the anode contactors are reclosed by reclosing relay (*T2*). If the trouble persists after several reclosures, one of the three double-pole temperature overload relays (*TR*-1-2-3) in the faulty circuit will open the coil circuit of its associated anode contactor and operation will be continued with the remaining phases and four tubes. The tubes are removed in pairs because the failure of one tube in a single-phase full-wave circuit produces saturation in its anode transformer and also reduces the average output voltage resulting in the remaining tube carrying practically no current. The opening of the contactor in one single-phase circuit changes the ripple frequency causing the operation of unbalanced relay (*UR*). The operating coil of this relay forms a part of a series tuned circuit connected across the d-c output (see figure 6). The unbalanced relay (*UR*) operates a relay (*T3*) to close the user's alarm or indicating circuit. If the disturbance has been one of repeated arcbacks, the defective tube can be identified through its element of the temperature relay in that phase.

If the tube fails to conduct because of lack of emission, the unbalanced relay (*UR*) will operate the alarm, no other relays operating. In this case the anode contactors will not be open, but the defective tube can be identified by

its lack of the characteristic blue glow as seen through the anode seal at the top of the tube. In order that a spare tube may be placed in operation, provision is made for holding it between the active tubes so that the radiated heat will keep it warm and the mercury properly distributed.

On the occurrence of a severe overload the control functions in the same manner as that for an arcback. If

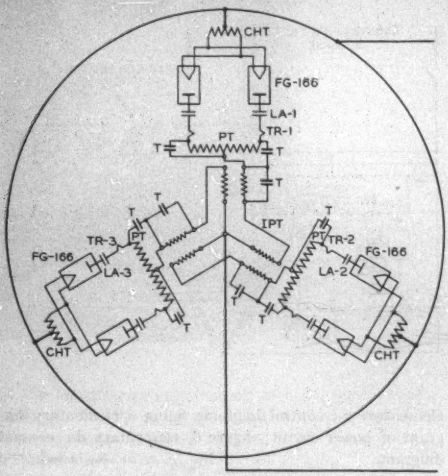


Figure 5. Elementary diagram of power circuit

CHT—Cathode-heater transformer *FG-166*—Phanotron tube
IPT—Interphase transformers *PT*—Power transformers
*LA*1, 2, 3—Anode contactors *T*—Thyrite arresters
*TR*1, 2, 3—Thermal relays

the overload persists for less time than required for the thermal relays to operate the anode contactors will reclose and normal operation will be resumed.

When connecting the rectifier to the source of supply, the cathode-heating transformers (*CHT*) (figures 4 and 5), are energized and supply excitation to the tubes. A timing relay (*T*1) is energized and after a predetermined time applies voltage to a reclosing timer (*T*2). In two seconds, voltage is applied to the closing coils (*LA*-1, 2, 3) of the three-tube anode contactors provided the control switch (*SW*) is closed. The closing of these contactors completes the circuit and makes power available.

The rectifier may be removed from the d-c load by opening switch (*SW*) which de-energizes contactors (*LA*-1, 2, 3) and opens the power circuit of the rectifier. However, the cathode-heater transformers remain connected to the power supply so that upon closure of *SW*, the rectifier is immediately reconnected to the load. Opening of the a-c power supply de-energizes the timing relay and power transformers. For the resumption of operation upon reclosure of the power supply switch, the timing cycle must be repeated after which the rectifier can be returned to service.

Overhauling Load

When the elevator is lowering a sufficiently heavy load, it holds speed by regenerative braking. Since the elevator rectifier cannot return this power to the supply circuit, it is necessary to provide a loading resistor which will absorb it. The loading resistor (*R*3) is shown in elementary d-c control diagram, figure 6.

The operation of the regenerative loading circuit is as follows: if power is supplied to the d-c output circuit, the coil of timing relay (*T*4) is energized through the loading resistor (*R*3), which relay completes the circuit of the instantaneous voltage relay (*VR*). When the rectifier operates with an overhauling load, the voltage on the d-c bus rises sufficiently above no load voltage to actuate voltage relay (*VR*) which in turn closes the loading resistor contactor (*L*) and allows it to absorb the overhauling load. The closing of contactor (*L*) also de-energizes the operating coil of the timing relay (*T*4), which after four seconds drops out, opening the voltage relay coil circuit so that the control is ready to repeat the cycle if the regenerative condition persists. As the regenerative power usually exists for much less than four seconds, generally one operating cycle is sufficient.

Power and Interphase Transformers

The transformers employed in these rectifiers are of the natural-draft air-cooled type as this construction provides the most economical design. As the transformers are located inside the cubicle (see figure 2) individual en-

R-1—Loading resistor
UR—Unbalance relay
CAP—Capacitor
VR—Voltage relay
R-2—Variable resistor
T-4—Timing relay
L—Contactor
R-3 — Regenerative loading resistor

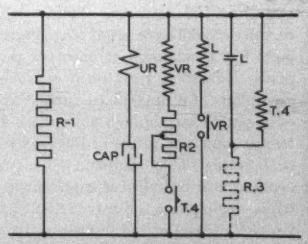


Figure 6. Elementary d-c control diagram

closing cases are not required. Transformers operating in rectifier circuits are subjected to transients during faulty operation. To protect the windings against any surge voltages that may be induced at such times, thyrite resistors (*T*) in figure 5 are connected across power transformer secondaries to neutral, and across one winding of each interphase transformer.

The triple single-phase circuit requires three interphase transformers. Each transformer has two independent sections connected zig-zag in order to cancel the d-c am-

pere turn under balanced load. The connection is equally effective with either two or three single-phase circuits in operation.

The design of the interphase transformer is of special importance in this particular service as the magnetizing current determines the point of inflection of the voltage regulation curve, figure 7. Slight manufacturing variations will naturally be encountered in similar circuits of identical design; hence, the d-c current supplied by each rectifier circuit will be different. To prevent saturation due to any small unbalance that may be present, the interphase transformers are constructed with an air gap. The magnetizing current being roughly proportional to the air gap, a small air gap is desirable in order that the inflection points occur at as light a d-c load as possible.

To provide the desired interphase transformer characteristics, the air gap is slotted, that is there is a small section of iron in the gap which produces a low-impedance flux path at light load, but which saturates very early under increased load, and so effectively lengthens the air gap. To prevent a high no-load voltage, a small loading resistor (R-1) (figure 6) rated 1.6 amperes is permanently connected across the d-c output. Its loss is only a small percentage of the no load loss of the rectifier.

Voltage Regulation

With the loading resistor in the circuit, the voltage at no load is about 257 volts and the voltage regulation of the elevator rectifier is approximately ten per cent as shown by the flat portion of solid line in figure 7. The dotted curve in figure 7 shows the regulation which would be obtained if one branch of the triple single-phase circuit were not operating. This latter regulation has been found to be sufficiently good to maintain substantially normal operation of the elevators.

Efficiency and Power Factor

The efficiency curve of the 40-kw, one-hour, 230-volt rectifier is very flat as shown in figure 8. This is materially better than can be obtained from a motor generator set of like rating, particularly at the light loads which are usually encountered with most elevator plants because of their low load factor. No-load losses are approximately 2.4 kw.

Figure 8 also shows the input power factor. It will be noted that this is very good even at no load, where the power factor is approximately 0.77. This is contrasted with a motor generator set having a no load loss of approximately 3.5 kw at a power factor of 0.25.

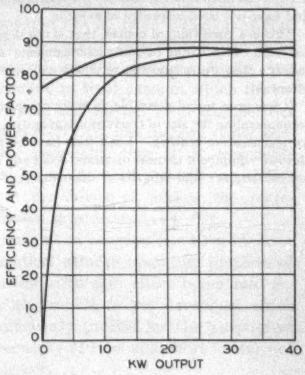


Figure 8. Power factor and efficiency 25 kw continuous, 40 kw, one hour, 240 volt, rectifier, no-load loss 2.4 kw

Summary

The triple single-phase phanotron rectifiers at the present time are built in capacities up to 40 kw at 230 volts and 75 kw at 550 volts. Their application has not been confined to elevator loads, one having been applied to general machine shop load including cranes, and another handling the entire building load elevators, ventilating fans, pumps, etc.

The units are self-contained with all live parts enclosed and if desired the cubicle may be locked. The installation wiring is limited to bringing in the a-c supply and connecting the d-c load. Installation costs are thus held to a minimum.

The operation of the seven rectifiers in service has to date been entirely successful. Additional rectifiers have been purchased by the original users after one year of use, indicating the suitability of the rectifier for hoisting service.

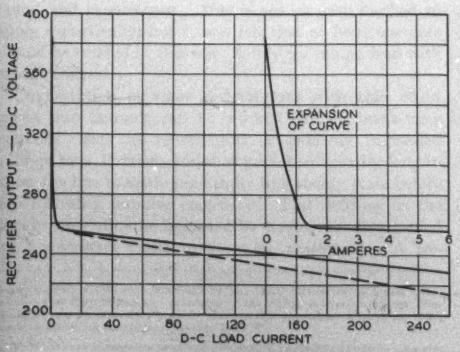


Figure 7. Voltage-regulation curve

Discussion

T. G. Glenn (General Electric Company, Chicago, Ill.): There are at present five 40-kw and two 25-kw, 250-volt phanotron rectifiers furnishing power for elevator equipment in the Chicago Loop area. These rectifiers supply power for elevators, both freight and pas-

senger, which in the majority of cases are in service 24 hours a day, seven days a week, so that the phanotron equipment is energized continuously. Because of this continuous service it is essential that the equipment operate with high no load efficiency.

The installations in the Chicago Loop area have been very successful and given remarkably satisfactory service. As the buildings in which they are installed are of a smaller office and manufacturing loft type, the electrical maintenance force is not of the caliber to give equipment the type of maintenance that rotating apparatus would require. In fact the equipments since their installation have seen little or no maintenance, and several of them are covered with dust and have not been inspected in months.

This is a condition, of course, that is not desirable and one which has been called to the building managements' attention, but it does indicate that the phanotron rectifiers will operate with little or no attention.

It has been found desirable to make complete load checks before recommending the size of conversion apparatus, or the size of resistor for regenerative braking. Load tests have been of an advantage as elevator equipment in most instances is old and nameplate ratings do not indicate the true capacity of the equipment.

As these phanotron rectifiers were installed in buildings where most of the available space is in use, rectifiers must be installed where space is available, sometimes this in the the basement and sometimes in an out of the way corner on one of the floors of the building. Our experience has shown that locations that were not suitable for rotating apparatus could be used for the rectifiers.

At first the electrical contractors who in general are installing the phanotron rectifiers, were skeptical of the equipment. This attitude perhaps was due to the equipment being new and unfamiliar to them, and contained electronic devices. However, the extreme simplicity of installation and wiring appeals to them. For instance, the wiring of a phanotron rectifier equipment requires only the installation of a three-wire incoming a-c line and a disconnect switch, and an outgoing two-wire d-c line to connect the load sides of the rectifier with the existing d-c mains in the building.

The long tube life experienced in these installations indicates a low maintenance cost.

The operating experience of the phanotron rectifiers in the Chicago area has shown that these units if properly installed, will furnish service comparable to that supplied from a 250-volt d-c system of the power company.

Transmission Line Transients in Motion Pictures

By L. F. WOODRUFF
MEMBER AIEE

IN SELECTING subjects for educational treatment by motion pictures at Massachusetts Institute of Technology, one of those favored was that of traveling waves on transmission lines. Reasons for the selection included the mathematical complexity of the subject and the difficulty of teaching it without spending an undue amount of time, and the fact that the phenomena which are involved are functions of both time and distance, and hence difficult to illustrate or visualize by ordinary methods. Experience in the use of the films with classes has shown that students' general understanding and appreciation of the subject are indeed greatly improved by viewing the motion pictures. The films which have been prepared have been and are now available in both the 16- and the 35-millimeter widths for free loan to other technical schools and associations.

In undertaking the work, it was decided that a true picture should be presented as far as was reasonably practicable. Waves computed on the basis of neglecting resistance and leakage would be very easy to show, since the resulting waves would be purely rectangular in shape. This method could not even allow showing the settling to the steady state. Computing the waves from the formulas for the distortionless line case ($R/L = G/C$) would be relatively easy, but the results would not be very appropriate since this condition presupposes an amount of leakage which is much greater than that present on any ordinary line. Furthermore, both of these foregoing methods involve neglecting skin effect and any other phenomena which result in the departure of the wave front from the vertical.

A better method of computing, but one which still neglects the factors which lead to a rounded wave front, is the one which results from the analysis based on uniformly distributed line constants of resistance, inductance, and capacitance. This is not an easy method to apply numerically, but it was felt that at least one case should be treated in this way, if only for comparison with other results.

Computation of wave distributions with skin effect taken into account can be worked out by brute-force methods, such as representing a suddenly impressed voltage by a Fourier's series of period sufficiently long to allow the line to settle practically to a steady state before the following impulse comes on. This settling to the steady state may be hastened by having the line loaded by a resistance equal to its surge impedance. A tremendous number of harmonics however must be handled even to approach fairly closely to the actual solution for a single time and position on the line. When it is considered that literally thousands of complete curves of distribution are required for the motion pictures, and further that it is desirable to treat cases in which the reflection at the load would add further great complexities in the calculation, it is seen that this method is not possible to apply in any reasonable time or at reasonable expense. Steinmetz[1] has made a very rough use of this method, but without the device of adding the surge-impedance load to hasten subsidence.

A rather meager amount of progress has been made in more direct mathematical attacks upon the problem of traveling wave behavior with skin effect taken into account, but there is no formula as yet developed which yields a solution sufficiently precise for the purpose at hand, or sufficient economy of time and effort to warrant its use for such a purpose.

Attention was turned therefore to methods of determining the data experimentally. The ideal source for the data would be a long actual power transmission line, but the practical difficulty of getting the use of such a line over a long enough period, and of taking observations at a large number of points along the line separated from one another by many miles, were very large.

Fortunately there have been available for a number of years in the electrical engineering laboratories at Technology, artificial transmission lines with distributed constants, designed by F. S. Dellenbaugh, Jr.[2] Comparisons of oscillograms taken of transients on these artificial lines and on actual overhead lines have shown that the characteristics of the laboratory lines are very nearly the same as those of actual lines. It was decided therefore to use, as the chief source of data, oscillograms taken at various points along one of these laboratory lines. Various types of load could be connected, and the transients and reflections resulting from complicated cases could be handled as easily as those from simple cases. A length of 250 miles was selected as being about equal to that of the longest existing lines. Relatively simple cases were selected for first treatment, since the purpose was an educational one.

On account of the rapidity of the transients and the steepness of the wave fronts, it was essential to use a cathode-ray oscillograph. In order to secure a standing image of the transient on the screen of the cathode-ray tube, and to obtain a time datum and comparative voltage datum with respect to the sending-end voltage, a special commutating device was developed to make it possible to give in effect a plurality of traces, of different currents or voltages, simultaneously on the screen. This device has been described in an earlier article.[3]

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1. For all numbered references, see list at end of paper.

Figure 1. Voltage - time - distance surface representing d-c switching transient on open line

It was decided that the films should be confined to showing variations of voltage, rather than bringing in current variations also, for several reasons. On power lines, when damage is done by traveling waves, it is by high-voltage rather than by high-current effects, and hence the voltage is practically more important. It is also easier to understand the entire phenomenon by watching a voltage wave rather than a current wave, because with the proportionality which exists between voltage and charge on a smooth line, an idea of the current is obtained readily by mentally applying the analogy of a mass of liquid moving along as a wave or surge. The only disadvantage in using voltage rather than current is that in the computation (which was used in one case for comparative purposes) the voltage is much more difficult and tedious to calculate. This disadvantage however can be overcome, as will be seen later.

Each oscillogram is a record of the time variation of voltage at some definite point on the artificial line, whereas the type of curve needed in preparing the motion pictures is a distribution of voltage along the entire length of the line, at a definite single instant of time. It was necessary therefore to replot the oscillographic data, transferring one ordinate from each oscillogram taken under a given set of line conditions, to a distribution curve. This was done by carefully ruling off all the 32 oscillograms which were taken for each case, by equal time intervals, and making use of a pair of proportional dividers to transfer and scale down the voltages recorded, at a particular length of time after energizing the line, on all the 32 oscillograms, to the distribution curve for that particular instant. Corrections for nonlinearity of the sweep time axis and other distortions were made in this process.

Direct Voltage on Open Line

The first case treated was that of the open-end line, with direct voltage suddenly impressed on the uncharged line at the sending end.

As an aid in visualizing the three-dimensional variation involving distance, time, and voltage, tracings of the oscillograms were made and glued to sheets of plywood, and then cut out along the curves by means of a jig saw. When these pieces are assembled in order, they form a three-dimensional plot of the variation of voltage, during the transient period, with both time and distance. A photograph of this solid figure for the open-line case is reproduced in figure 1.

With reference to this solid figure, each voltage distribution curve may be visualized as a thin slice of the figure made in a direction perpendicular to the plane of the plywood pieces and to the base.

The voltage distribution curves for a number of instants of time are shown in figure 2. It is seen that the wave undergoes attenuation and distortion during its travel, and the wave front becomes progressively less and less steep. Complete reflection at the open end takes place without a change of sign, resulting in a voltage nearly twice the impressed voltage for a short time. Reflection

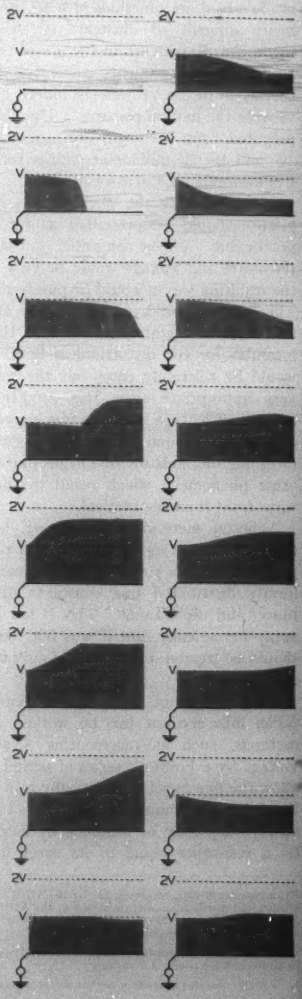

Figure 2. Direct-voltage waves on open line

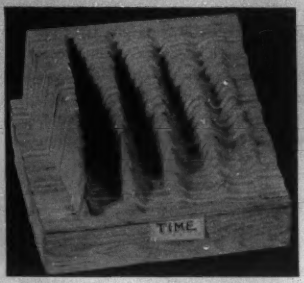

Figure 3. Direct-voltage switching transient on short-circuited line

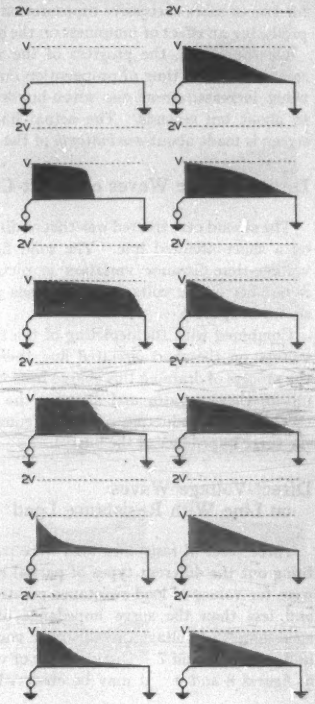

Figure 4. Direct-voltage waves on short-circuited line

at the sending end occurs with a reversal of sign, and after several trips of the wave over the line the distribution is obviously approaching the steady state of a voltage along the whole line equal to the impressed voltage. This is in the absence of any appreciable leakage on the line.

Technique of Actual Photography

When distribution curves had been plotted in the manner already explained, dark paper cutouts were made with scissors to fit the distributions. These were then glued to white paper background sheets, which had perforations to locate them precisely over pins on a platform under a motion-picture camera. The procedure was quite similar to that used in animated cartoon motion pictures. The background drawings of the transmission line, scale lines, generator, and terminal connection in the animation scenes were made on celluloid. These were then printed photographically on film to avoid trouble due to chipping off the ink, which occurred when the original drawings on transparent celluloid were used repeatedly. Transparencies were used also in obtaining a number of special effects, including rotating commutators, closing switches, sections of wave moved and inverted to illustrate the action of complete reflection.

In order to economize on the labor required, the distribution plots were not made independently for each frame of the motion picture. One was made for every eighth frame, and the distributions in between were determined by graphical interpolation first into halves, then quarters, and finally eighths. One hundred twenty-eight different views were prepared to produce a transit of the wave from one end of the line to the other. As the steady state was approached and the motion became very slow, it was found possible to use one distribution diagram

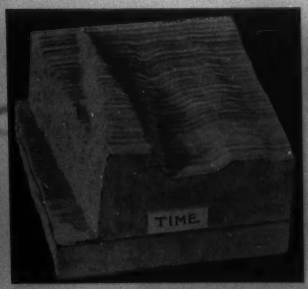

Figure 5. Direct-voltage switching transient on line loaded with resistance greater than surge impedance

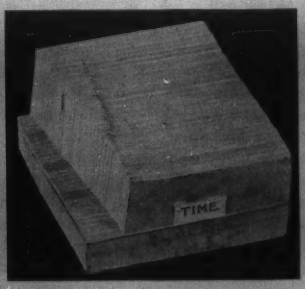

Figure 6. Direct-voltage switching transient on line loaded with resistance equal to surge impedance

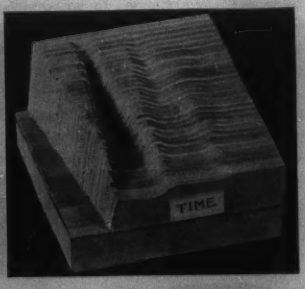

Figure 7. Direct-voltage switching transient on line loaded with resistance less than surge impedance

for two or more successive exposures on the film, without producing an effect of jumpiness on the screen.

On the screen, the progress of the wave is shown in slow motion, its time of propagation on the 250-mile line being increased from one seven-hundred-fiftieth second to about ten seconds. The actual linear speed on the screen is made about *one billionth* of the actual speed.

Direct-Voltage Waves on Short-Circuited Line

The second case treated was that of direct-voltage waves on a short-circuited line. The solid figure showing the voltage-time-distance variation is pictured in figure 3. A number of the voltage distributions along the line are shown in figure 4.

Combined with the depicting of the building up of the voltage on the short-circuited line, there was shown also the process of draining this charge from the line by switching off the generator and allowing the line to discharge through a noninductive resistance equal numerically to the surge impedance of the line.

Direct-Voltage Waves on Line With Resistance Load

Three cases of resistance load were treated in order to bring out the different types of partial reflection. These were for values of load resistance greater than, equal to, and less than the surge impedance of the line. The solid figures of voltage-time-distance variation are shown in figures 5, 6, and 7. Distributions of voltage are shown in figures 8 and 9. It may be observed in figure 8 that partial reflections without a change of sign occur at a resistor termination whose resistance is greater than the surge impedance. No reflection occurs when the termination has a noninductive resistance equal to the surge impedance. Partial reflections with change of sign are shown in figure 9, which is for the line with termination having noninductive resistance less than the surge impedance.

Direct-Voltage Waves on Line With Inductive Load

The case of voltage waves striking an inductive termination was treated. The three-dimensional plot, made by packing together 33 oscillograms pasted on plywood and cut out along the curves, is pictured in figure 10. Plots of voltage distribution are shown in figure 11.

It may be observed that when the voltage wave first strikes the inductive load, there is an approximately complete reflection without a change of sign, just as is the case when the wave strikes an open end. The reason for this is that the flow of current along the line accompanying this voltage wave is temporarily halted by the inductance. In order for the current to flow on without delay into the inductance, an infinite rate of change of current there would be required, if there were no distributed capacitance in the inductor itself. The rate of change of current build-up can occur only at a rate such that the back emf produced by the inductance will equal the voltage impressed on the inductance. This initial stoppage of the current causes the charge to build up just as in the open-line case, but soon the current begins to flow in appreciable

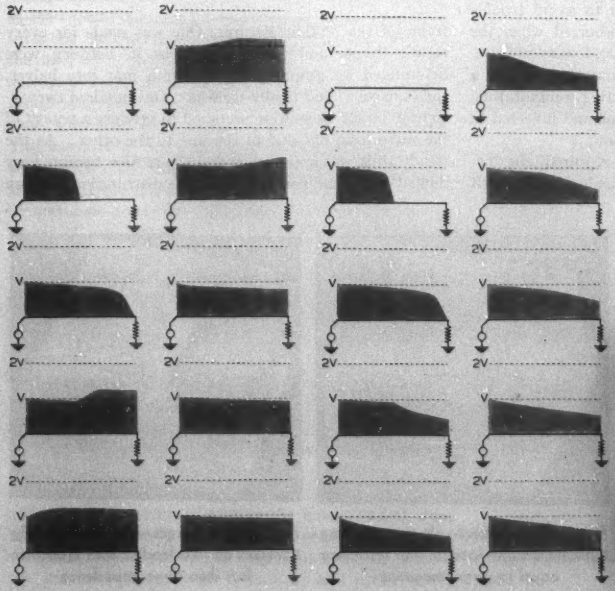

Figure 8 (extreme left). Direct-voltage waves on line loaded with resistance greater than surge impedance

Figure 9 (left). Direct-voltage waves on line loaded with resistance less than surge impedance

Figure 10 (below). Direct-voltage switching transient on line with inductive load

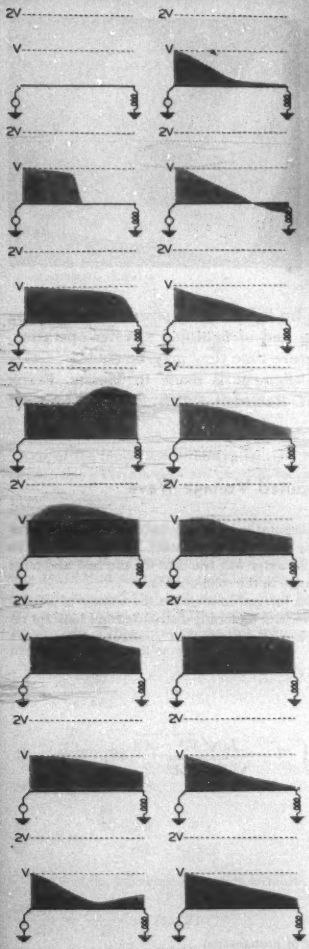

Figure 12 (above). Direct-voltage switching transient on line with capacitive load

Figure 11 (left). Direct-voltage waves on line with inductive load

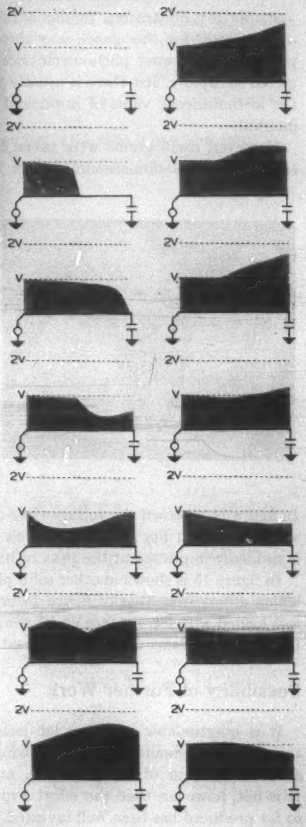

Figure 13 (right). Direct-voltage waves on line with capacitive load

quantity through the inductance, draining some of the charge off the line and reducing the voltage. The size of the inductance used as a load in these tests was approximately the same as that of the entire 250 miles of line—about one henry.

When the original wave has reflected from the load, and the reflection returned to the sending end, its sign becomes reversed, and when it travels down toward the load end again, its sign is negative. This negative wave reaches the load and undergoes a negative reflection, at a time when the voltage at and near the load has been greatly reduced by the continuously increasing current which is being drained away by the inductive load. As a result, the net voltage at the load and near it goes below zero and takes on a very considerable negative value.

Direct-Voltage Waves on Line With Capacitive Load

Another case treated was that of direct-voltage waves on a line with a termination of capacitance. The solid figure of voltage-time-distance variation for this case is shown in figure 12; and plots of distribution at different instants of time in figure 13. It will be observed that the initial reflection is similar to that on a short-circuited line, since the load end is maintained at zero voltage until a finite and sufficient time has elapsed to allow a finite quantity of charge to accumulate in the condenser. The action as this charge accumulates can be traced by the rise of the voltage behind the wave front of the first reflection as it makes its way back toward the sending end.

Alternating-Voltage Waves

No motion pictures have been made as yet of the alternating-voltage waves. It was felt that the comparative simplicity of the d-c phenomena made the d-c case more

valuable for illustrating fundamental phenomena. Another reason for the choice was the fact that for most power lines the wave phenomena take place and are completed so rapidly that there is usually very little change in the instantaneous value of impressed voltage during the interval.

However, oscillograms were taken for a number of a-c cases, and three-dimensional figures built up as before.

Figure 14. Alternating - voltage switching transient on open line

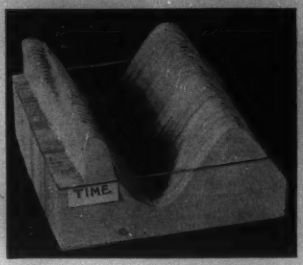

Figure 15. Alternating - voltage switching transient on line loaded with resistance greater than surge impedance

In figure 14 is shown the voltage-time-distance relation on a 250-mile open line when a 60-cycle-per-second voltage is suddenly impressed at the peak of its wave.

In figure 15 is shown another solid plot for the a-c case, which differs from that of figure 14 only in that the line was loaded with a resistance equal to approximately twice the surge impedance of the line, instead of being open.

Possibility of Further Work

It is questionable just how far treatment of different types of wave should be carried, owing to the very considerable amount of expense, time, and effort involved. It is felt, however, that the effort expended on the films so far produced has been well invested.

Additional oscillographic data have been taken of waves on a large lead-covered telephone cable which was generously lent for the purpose by Bell Telephone Laboratories, Inc. Tests were made without loading and with loading coils at the usual intervals, for direct current and for 1,000-cycles-per-second alternating current impressed. These data are in form sufficiently complete to form the basis for a number of traveling-wave films showing telephone-transmission phenomena, if they should be undertaken in the future.

If these films were to be made for the a-c case it appears that the best method of procedure in the preparation of the master distribution diagrams would be to work from the d-c distributions by applying the superposition formula,[4] using a mechanical method of integration. By doing this, various frequencies may be treated, as may the impressing of the voltage at different parts of the cycle, and even complex waves representing speech. Voltages of two widely separated frequencies, superposed and traveling along the line, would illustrate effects of amplitude and phase distortion.

It would undoubtedly be most interesting to see films of waves produced by lightning on power lines, showing the effect of corona and of lightning arrester operation. Perhaps at some future time they may be made.

Grateful acknowledgment is made to Messrs. Frank H. Conant, Philip H. Ramsdell, and B. E. Battit for their parts in the work.

Appendix—Computed Voltage Wave

It was desired for comparative purposes to show a voltage wave computed on the basis of assumed constant line parameters, as already stated. The literature was searched for the best and most practicable formulas to use in the computation.

J. R. Carson[4] gives an integral formula for the voltage as a function of x and t, on a line with uniformly distributed and constant resistance R, inductance L, and capacitance C (leakage zero) per unit length, as follows:

$e(x,t) = 0$ for $vt < x$.

For $vt \geq x$,

$$e(x,t) = Ee^{-A} + EA \int_A^T \frac{e^{-T_1} \cdot I_1(\sqrt{T_1^2 - A^2})}{\sqrt{T_1^2 - A^2}}\, dT_1$$

where

$$A = \frac{R}{2}\sqrt{\frac{C}{L}}\, x$$

$$T = \frac{R}{2L}\, t$$

$$v = \frac{1}{\sqrt{LC}} = \text{velocity of propagation}$$

E = size of suddenly impressed d-c voltage

V. Bush[5] gives the following solution, following Heaviside[6]:

$$e(x,t) = Ee^{-\rho t}\left[1 + \left(\frac{x\sigma^2}{2v} + \rho\right)\left(t - \frac{x}{v}\right) + \left(\frac{x^2\sigma^4}{2^2 2!^2 v^2} + \frac{x\sigma^2\rho}{2^2 v} + \frac{\rho^2}{2!}\right)\left(t - \frac{x}{v}\right)^2 + \ldots\right]$$

noting that it is useful for computation only when $(t - x/v)$ is small. In the above, the new symbols have the following definitions:

$$\rho = \frac{R}{2L} + \frac{G}{2C}$$

$$\sigma = \frac{R}{2L} - \frac{G}{2C}$$

It may be noted that when the leakage G is equal to zero, $\rho = \sigma = R/2L$.

Now a fairly simple formula is available for the computation of the *current* wave on a nonleaky line, and in view of the simplicity of the relation which exists between current and voltage, it was decided to attempt to determine the voltage by performing the necessary operations on the known current solution.

We have from Heaviside and may later writers the current-wave formula for the nonleaky line, as follows, for $x \lesseqgtr vt$:

$$i = E\sqrt{\frac{C}{L}}\,\epsilon^{-\frac{Rt}{2L}}\,I_0\left[\frac{R}{2L}\sqrt{t^2-\frac{x^2}{v^2}}\right] \tag{1}$$

In equation 1 I_0 designates the Bessel function of the first kind and zero order, for pure imaginary argument. Let the abbreviation Z be introduced, equal to

$$Z = \frac{R}{2L}\sqrt{t^2-\frac{x^2}{v^2}} = \frac{R}{2Lv}\sqrt{(vt-x)(vt+x)} \tag{2}$$

so that (1) simplifies to

$$i = E\sqrt{\frac{C}{L}}\,\epsilon^{-\frac{Rt}{2L}}\,I_0(Z) \tag{3}$$

One of the fundamental differential equations upon which transmission-line wave solutions are based is, for zero leakage,

$$\frac{\partial e}{\partial t} = -\frac{1}{C}\frac{\partial i}{\partial x} \tag{4}$$

The value of i given in equation 3 will be substituted into equation 4, and then solution for e will be made. Throughout the following, it is assumed that $0 < x < vt$. It is known of course that for $x > vt$ the voltage $e = 0$. It is assumed that we are dealing with an infinite line, although of course this solution is applicable to finite lines by proper handling of the reflections.

$$\frac{\partial Z}{\partial x} = -\frac{R^2x}{4L^2v^2Z} \tag{5}$$

$$\frac{\partial Z}{\partial t} = \frac{R^2t}{4L^2Z} \tag{6}$$

From (3), (4), and (5),

$$\frac{\partial e}{\partial t} = E\,v\epsilon^{-\frac{Rt}{2L}}\frac{\partial I_0(Z)}{\partial Z}\cdot\frac{R^2x}{4L^2v^2Z} \tag{7}$$

We have the following recurrence formula[7] for Bessel functions:

$$\frac{\partial I_n(Z)}{\partial Z} = \frac{nI_n(Z)}{Z} + I_{n+1}(Z) = I_{n-1}(Z) - \frac{nI_n(Z)}{Z} \tag{8}$$

From the resemblance which equation 7 bears to $\partial i/\partial t$ it can be seen that by adding and subtracting the quantities in the brackets below, a portion of the expression can be made a perfect differential with respect to t.

$$\frac{\partial e}{\partial t} = E\epsilon^{-\frac{Rt}{2L}}\frac{\partial I_0(Z)}{\partial Z}\frac{R^2x}{4L^2vZ} + E\Bigg[\epsilon^{-\frac{Rt}{2L}}\frac{\partial I_0(Z)}{\partial Z}\frac{R^2(vt-x)}{4L^2vZ} - \epsilon^{-\frac{Rt}{2L}}\frac{\partial I_0(Z)}{\partial(Z)}\frac{R}{2L}\sqrt{\frac{vt-x}{vt+x}} + \frac{R}{2L}\epsilon^{-\frac{Rt}{2L}}I_0(Z) - \frac{R}{2L}\epsilon^{-\frac{Rt}{2L}}I_0(Z)\Bigg]$$

$$= E\Bigg[\epsilon^{-\frac{Rt}{2L}}\frac{\partial I_0(Z)}{\partial Z}\frac{R^2t}{4L^2Z} - \frac{R}{2L}\epsilon^{-\frac{Rt}{2L}}I_0(Z)\Bigg] - E\epsilon^{-\frac{Rt}{2L}}\frac{\partial I_0(Z)}{\partial Z}\frac{R}{2L}\sqrt{\frac{vt-x}{vt+x}} + E\frac{R}{2L}\epsilon^{-\frac{Rt}{2L}}I_0(Z) \tag{9}$$

By the recurrence formula, equation 8, it is seen that $\partial I_0(Z)/\partial Z$ in the second term of equation 9 may be replaced by $I_1(Z)$. We have further the general relation that

$$\int u\,v\,dw = u\,v\,w - \int u\,w\,dv - \int v\,w\,du \tag{10}$$

which it is convenient to apply to this same second term, with

$$u = \frac{\partial I_0(Z)}{\partial Z} \text{ or } I_1(Z)$$

$$v = \sqrt{\frac{vt-x}{vt+x}}$$

$$dw = -\frac{R}{2L}\epsilon^{-\frac{Rt}{2L}}\,dt$$

The entire expression for $\frac{\partial e}{\partial t}$ is then integrated with respect to t, giving:

$$e = f(x) + E\epsilon^{-\frac{Rt}{2L}}I_0(Z) + E\epsilon^{-\frac{Rt}{2L}}I_1(Z)\sqrt{\frac{vt-x}{vt+x}} + E\int\Bigg\{-\epsilon^{-\frac{Rt}{2L}}\frac{\partial I_1(Z)}{\partial Z}\frac{R^2t}{4L^2Z}\sqrt{\frac{vt-x}{vt+x}} - \epsilon^{-\frac{Rt}{2L}}I_1(Z)\frac{vx}{(vt+x)^2}\times\sqrt{\frac{vt+x}{vt-x}} + \frac{R}{2L}\epsilon^{-\frac{Rt}{2L}}I_0(Z)\Bigg\}dt \tag{11}$$

Using the recurrence formula (8) again and substituting for $\partial I_1(Z)/\partial Z$ and $I_0(Z)$ there results, for the integral term:

$$e = \ldots + E\int\Bigg\{-\epsilon^{-\frac{Rt}{2L}}I_1(Z)\frac{R^2t}{4L^2Z^2}\sqrt{\frac{vt-x}{vt+x}} - \epsilon^{-\frac{Rt}{2L}}I_2(Z)\frac{R^2t}{4L^2Z}\sqrt{\frac{vt-x}{vt+x}} - \epsilon^{-\frac{Rt}{2L}}I_1(Z)\frac{vx}{(vt+x)^2}\sqrt{\frac{vt+x}{vt-x}} + \frac{R}{2L}\epsilon^{-\frac{Rt}{2L}}\left[I_2(Z) + \frac{2I_1(Z)}{Z}\right]\Bigg\}dt \tag{12}$$

Substituting in (12) the value of Z from (2), and simplifying, there results:

$$e = \ldots + E\int\Bigg\{-\epsilon^{-\frac{Rt}{2L}}I_1(Z)\left[\frac{v^2t}{(vt+x)^{3/2}(vt-x)^{1/2}} + \frac{vx}{(vt+x)^{3/2}(vt-x)^{1/2}} - \frac{2v}{(vt+x)^{1/2}(vt-x)^{1/2}}\right] + \epsilon^{-\frac{Rt}{2L}}I_2(Z)\left[\frac{R}{2L} - \frac{Rvt}{2L(vt+x)}\right]\Bigg\}dt \tag{13}$$

The first two terms of the first bracket in (13) have a common denominator, and together they equal half the negative value of the third term. These terms come from the term in equation 11 containing $\partial I_1(Z)/\partial Z$ and the succeeding term. If the signs of these terms in (11) are reversed, the result is a doubling of the two terms referred to in (13), which will cause the entire first bracketed expression to become zero. In order to compensate for this change in sign, we must add

$$E\epsilon^{-\frac{Rt}{2L}}I_1(Z)\sqrt{\frac{vt-x}{vt+x}}$$

to the integral portion of e, as may be seen by inspection of (10) and

(11). We then have:

$$e = f(x) + Ee^{-\frac{Rt}{2L}} I_0(Z) + 2Ee^{-\frac{Rt}{2L}} I_1(Z)\sqrt{\frac{vt-x}{vt+x}} +$$

$$E\int\left\{\frac{R}{2L}e^{-\frac{Rt}{2L}} I_0(Z)\left[1-\frac{2vt}{vt+x}\right]+\right.$$

$$\left. e^{-\frac{Rt}{2L}}\frac{\partial I_0(Z)}{\partial Z}\frac{R}{2L}\sqrt{\frac{vt-x}{vt+x}}\right\}dt$$

$$= \ldots + E\int\left\{-\frac{R}{2L}e^{-\frac{Rt}{2L}}\left(\frac{vt-x}{vt+x}\right)I_0(Z) + \right.$$

$$\left.\frac{R}{2L}e^{-\frac{Rt}{2L}}\sqrt{\frac{vt-x}{vt+x}}\,I_2(Z)\right\}dt \quad (14)$$

Now we may take the integral term at the end of equation 14 and operate upon it in a manner similar to that used in integrating and reducing the last two terms of equation 9. There results:

$$E\int\left\{-\frac{R}{2L}e^{-\frac{Rt}{2L}}\left(\frac{vt-x}{vt+x}\right)I_0(Z)+\frac{R}{2L}e^{-\frac{Rt}{2L}}\sqrt{\frac{vt-x}{vt+x}}\,I_1(Z)\right\}dt =$$

$$2Ee^{-\frac{Rt}{2L}}\left(\frac{vt-x}{vt+x}\right)I_2(Z) + E\int\left\{-\frac{R}{2L}e^{-\frac{Rt}{2L}}\left(\frac{vt-x}{vt+x}\right)^{3/2}I_2(Z)+\right.$$

$$\left.\frac{R}{2L}e^{-\frac{Rt}{2L}}\left(\frac{vt-x}{vt+x}\right)I_2(Z)\right\}dt \quad (15)$$

It is seen that each integration results in another integral of the same character but of order one higher, and a by-product of an additional term outside the integral. The evaluation of the integral may be generalized for the nth term as follows:

$$E\int\left(\frac{vt-x}{vt+x}\right)^{n/2}\frac{R}{2L}e^{-\frac{Rt}{2L}}\left[-I_{n+1}(Z)\left(\frac{vt-x}{vt+x}\right)^{1/2}+I_n(Z)\right]dt =$$

$$2Ee^{-\frac{Rt}{2L}}\left(\frac{vt-x}{vt+x}\right)^{\frac{n+1}{2}}I_{n+1}(Z) + E\int\left(\frac{vt-x}{vt+x}\right)^{\frac{n+1}{2}}\times$$

$$\frac{Re}{2L}^{-\frac{Rt}{2L}}\left[-I_{n+2}(Z)\left(\frac{vt-x}{vt+x}\right)^{1/2}+I_{n+1}(Z)\right]dt \quad (16)$$

The relation expressed in (16) was obtained by induction, but a direct proof of it may be had by differentiating it with respect to t.

The voltage wave may be expressed:

$$e(x,t) = f(x) + Ee^{-\frac{Rt}{2L}} I_0(Z) +$$

$$2Ee^{-\frac{Rt}{2L}}\sum_{n=1}^{\infty} I_n(Z)\left(\frac{vt-x}{vt+x}\right)^{n/2} \quad (17)$$

If the line is initially uncharged, $f(x)$ is equal to zero. There is a discontinuity at $x = vt$, and equation 17 indicates a wave front (which exists where this condition holds) of magnitude

$$Ee^{-\frac{Rt}{2L}}$$

The magnitude of the current wave front, found by substituting $x = vt$ in equation 3, is

$$E\sqrt{C/L}e^{-\frac{Rt}{2L}}$$

The wave front is advancing at a velocity $v = 1/\sqrt{LC}$, and it is seen that this flow of current is just sufficient to charge up the line at this rate and to the magnitude indicated as being required by the expression for the voltage wave front. The voltage solution is therefore compatible with the current solution at the point of discontinuity.

For $x > vt$, the voltage is everywhere zero, since no charge has yet been brought to that part of the line by the oncoming current wave.

Let the new symbol s be introduced, defined as:

$$s = \sqrt{\frac{vt-x}{vt+x}} \quad (18)$$

Then the expression for the original voltage wave, due to a direct voltage E suddenly impressed on a transmission line with constants R, L, and C, is:

$$e = Ee^{-\frac{Rt}{2L}}\{I_0(Z) + 2sI_1(Z) + 2s^2I_2(Z) + 2s^3I_3(Z) + \ldots)\} \quad (19)$$

where

$$I_n(Z) = \frac{Z^n}{2^n n!}\left\{1+\frac{Z^2}{2^2 1!(n+1)}+\frac{Z^4}{2^2 2!(n+1)(n+2)}+\ldots\right\} \quad (20)$$

In a similar manner, the more complicated case of the line with all four constants R, L, C, and G may be worked out in terms of Bessel functions. The result is:

$$e = Ee^{-ut}\{I_0(Z) + 2rsI_1(Z) + (4r^2-2)s^2I_2(Z) +$$
$$(8r^3-6r)s^3I_3(Z) + (16r^4-16r^2+2)s^4I_4(Z) +$$
$$(32r^5-40r^3+10r)s^5I_5(Z) + (64r^6-96r^4+36r^2-2)s^6I_6(Z) +$$
$$(128r^7-224r^5+112r^3-14r)s^7I_7(Z) +$$
$$(256r^8-512r^6+320r^4-64r^2+2)s^8I_8(Z) + \ldots.\} \quad (21)$$

In the above, the symbols have all already been defined except r, which is defined as $\frac{\rho}{\sigma}$, and Z is made equal to

$$\sigma\sqrt{t^2-\frac{x^2}{v^2}}$$

Equation 19 is the one which was used in the computation of the voltage distributions for the motion picture.

A table of Bessel functions of orders from 0 to 11, and covering the range of argument required, is available in the Report of the British Association for 1896.

In the artificial line used, which was made up of 32 sections of the single-phase line described in Dellenbaugh's paper,[2] the constants were:

	Per Section	32 Sections
Resistance	7.9 ohms	252.8 ohms
Inductance	0.0326 henry	1.043 henries
Capacitance	0.0565 microfarad	1.808 microfarads
Equivalent length	7.87 miles	251.84 miles

The computation for voltage distribution was carried out for a range of x and vt between 0 and 12 times the length of the line (0 and 384 sections), at intervals of one quarter of the length or eight sections. A few of the early results are given in table I, which is reproduced only in small part on account of the large size of the complete table.

For the open-line case, the reflection from the end is complete and without change of sign. To illustrate the numerical computation, let $vt = 40$ sections, or one and one-fourth times the length of line. Then the section of the wave indicated in table I as lying between $x = 32$ and $x = 40$ has actually turned around and gone back from 32 to 24. The wave front is at section 24 and moving toward the generator. The distribution is

x(section) =	0	8	16	24	32
e/E =	1.000	0.962	0.925	0.887 1.699	1.700

The first three figures and the upper figure under section 24 are

Table I. Values of Computed Voltage $e(x,t)$ per Volt Impressed

t (Sections) \ x (Sections)	0	8	16	24	32	40	48
0	1.000	0	0	0	0	0	0
8	1.000	0.959	0	0	0	0	0
16	1.000	0.960	0	0.920	0	0	0
24	1.000	0.9605	0	0.921	0	0.883	0
32	1.000	0.9613	0	0.923	0	0.885	0
40	1.000	0.962	0	0.925	0	0.887	0
48	1.000	0.963	0	0.926	0	0.889	0
						0.852	0
						0.816	0
							0.779

taken directly from table I. The other entry under section 24 is the sum of the table I entries for sections 24 and 40. The entry under section 32 is twice the corresponding entry in table I. The two entries under section 24 represent the values of the wave at the top and bottom of the wave front there.

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7. Theory of Bessel Functions, Watson.

Discussion

John Riordan (nonmember; Bell Telephone Laboratories, Inc., New York, N. Y.): I wish to present a verification of the expansion given as equation 21 in the appendix to Mr. Woodruff's paper; this is the general result of the development in the appendix. I should explain at once that the process I use is not a substitute for Mr. Woodruff's original method; given the form of the expansion by Mr. Woodruff, it will determine the coefficients and verify the form, but it requires either this advance information or an act of inspiration to be complete. However, I am able by its means to give a generating function, a literal formula, and a recurrence formula for the coefficients of the general expansion, equation 21, thus completing Mr. Woodruff's work. The coefficients turn out to be simply related to the Tchebycheff polynomials.

Using the notation of the paper with a slight modification, the expansion to be verified is as follows:

$$e = E \sum_{n=0}^{\infty} C_n(r) s^n I_n(\sigma z) \exp(-\rho t)$$

where

$C_n(r)$ = function of r and n which is the coefficient of the nth term in equation 21.

$r = \rho/\sigma$

$z = [t^2 - x^2/v^2]^{1/2}$

Using the Campbell and Foster table of Fourier integrals (Bell Telephone System Technical Publications, Monograph *B*-584), by pair 870.5:

$$\mathfrak{M}[s^n I_n(\sigma z) \exp(-\rho t)] = \frac{(2\sigma)^n \exp\left[\frac{-x}{v}\sqrt{(p+\rho)^2 - \sigma^2}\right]}{\sqrt{(p+\rho)^2 - \sigma^2}\,[\sqrt{p+\rho+\sigma} + \sqrt{p+\rho-\sigma}]^{2n}}$$

where the script $\mathfrak{M}$ is to be read "mate of" or "Fourier transform of."

Hence the original expansion may be written

$$\mathfrak{M}(e) = E \frac{\exp\left[\frac{-x}{v}\sqrt{(p+\rho)^2 - \sigma^2}\right]}{\sqrt{(p+\rho)^2 - \sigma^2}} \sum_{n=0}^{\infty} C_n(r) u^n$$

where

$$u = \frac{2\sigma}{[\sqrt{p+\rho+\sigma} + \sqrt{p+\rho-\sigma}]^2} = \frac{\sigma}{p+\rho+\sqrt{(p+\rho)^2 - \sigma^2}}$$

But the mate of e is known otherwise (Campbell and Foster, l.c. table II, case 3) as:

$$\mathfrak{M}(e) = \frac{E}{p} \exp\left[\frac{-x}{v}\sqrt{(p+\rho)^2 - \sigma^2}\right]$$

Hence $C_n(r)$ is determined, assuming the form of the expansion is correct, by:

$$\sum_{n=0}^{\infty} C_n(r) u^n = \frac{\sqrt{(p+\rho)^2 - \sigma^2}}{p}$$

If the right-hand side may be expressed as a function of u and r the expansion is correct and the expression so obtained is the generating function of $C_n(r)$. Writing $W = \sqrt{(p+\rho)^2 - \sigma^2}$, for convenience, this may be done as follows:

$$\frac{W}{p} = \frac{W(p+W)}{p(p+W)} = \frac{p(p+W) + 2\rho p + \rho^2 - \sigma^2}{p(p+W)}$$

$$= 1 + \frac{2\rho}{p+W} + \frac{(\rho^2 - \sigma^2)(p+W)}{p(p+W)^2}$$

$$= 1 + \frac{2\rho}{p+W} + \frac{\rho^2 - \sigma^2}{(p+W)^2} + \frac{W}{p}\frac{\rho^2 - \sigma^2}{(p+W)^2}$$

Hence, noting that $p + W = -\rho + \sigma/u$:

$$\frac{W}{p}\left[1 + \frac{(1-r^2)u^2}{(1-ru)^2}\right] = 1 + \frac{2ru}{1-ru} - \frac{(1-r^2)u^2}{(1-ru)^2}$$

or

$$\frac{W}{p} = \frac{1-u^2}{1-2ru+u^2}$$

which is the required generating function expression.

But the Tchebycheff polynomials $T_n(r)$ (Courant and Hilbert, Methoden der Math. Physik, Springer, Berlin, 1931, pages 75 and 76) defined by

$$T_n(r) = \frac{1}{2^{n-1}} \cos[n \cos^{-1} r]$$

have the generating identity:

$$\frac{1-x^2}{1-2rx+x^2} = \sum_{n=0}^{\infty} T_n(r)(2x)^n$$

Hence

$$C_n(r) = 2^n T_n(r) = 2\cos[n \cos^{-1} r]$$

and for $n \geq 2$:

$$T_{n+1}(r) = rT_n(r) - \frac{1}{4} T_{n-1}(x)$$

$$C_{n+1}(r) = 2rC_n(r) - C_{n-1}(r)$$

the last of which is the recurrence relation for the coefficients. For

convenience of comparison with Mr. Woodruff's result, the first few coefficients are as follows:

$$C_0(r) = 1$$
$$C_1(r) = 2r$$
$$C_2(r) = 4r^2 - 2$$
$$C_3(r) = 8r^3 - 6r$$

The first three follow from the literal formula, the last from the recurrence formula; they may also be obtained by simple long division development of the generating function.

In the special case $G = 0$, that is $\rho = \sigma$ and $r = 1$, the nth coefficient is

$$C_0(1) = 1$$

$$C_n(1) = 2 \neq 0$$

which verifies equation 19. This result follows immediately either from the generating function or the formula for $C_n(r)$.

I am indebted to my colleague S. O. Rice for pointing out the connection of the coefficients with the Tchebycheff polynomials.

L. V. Bewley (General Electric Company, Pittsfield, Mass.): Professor Woodruff has shown two very interesting and instructive methods of teaching transmission line transients by means of motion pictures and voltage-distance-time models. These should prove of great value to schools in which traveling wave phenomena is taught; because it gives the student a perfect visual picture of what is going on during the travel and reflection of a wave.

Along about 1929 we calculated the wave shapes for lightning surges and worked out the reflections for a number of terminal conditions, ("Traveling Waves Due to Lightning," AIEE TRANSACTIONS, volume 48, 1929). At that time F. W. Peek, Jr., was directing the lightning research at Pittsfield and he asked J. T. Lusignan, Jr., to supervise the making of an animated motion picture based on the calculated wave shapes. This film (General Electric *AX-353-B*) was shown by Mr. Peek before many different AIEE Sections throughout the country. It depicts the formation of a charged cloud; the lightning stroke; the formation and development of the traveling waves; the attenuation due to corona; reflections from open and grounded terminals and from a resistor equal to the surge impedance of the line, also from transformer terminals and series inductances with and without shunt resistors; and finally the internal transient oscillations taking place inside a transformer winding and their elimination by means of shields.

Several years ago D. C. Morgan at Pittsfield conceived the idea of illustrating the internal transient of a transformer by a topographical voltage-distance-time model, just as Professor Woodruff has now done for transmission lines. Figure 1 is a photograph of Morgan's plaster-cast model.

Figure 1

Discussions

of AIEE Technical Papers Published Before Discussions Were Available

ON THIS and the following 21 pages appear discussions submitted for publication, and approved by the technical committees, on previously published papers presented at the AIEE winter convention, New York, N. Y., January 24–28, 1938. Authors' closures, where they have been submitted, will be found at the end of the discussion on their respective papers.

Alternator Short-Circuit Currents Under Unsymmetrical Terminal Conditions

Discussion of a paper by A. R. Miller and W. S. Weil, Jr., published on pages 1268–76 of volume 56, 1937, AIEE TRANSACTIONS (October 1937 issue of ELECTRICAL ENGINEERING) and presented for oral discussion at the electrical machinery session of the winter convention, New York, N. Y., January 27, 1938.

F. H. Pumphrey (Rutgers University, New Brunswick, N. J.): I have been very much interested in the effort of Professor Miller and Mr. Weil to digest the work which has been done in machine transients and to present it in somewhat simpler form. The necessity of conforming with the Institute publication standards has prevented them from making a complete statement of assumptions. It thus becomes rather difficult to follow some of the steps and so the paper loses some of its advantage of completeness as well as simplicity.

In this connection, I have been unable to interpret physically the very low frequency element of armature current given on page 1269 I wonder if it might not be obtained equally accurately by a constant term with a different decrement? I should appreciate any help the authors could give on this interpretation.

Another question has arisen with respect to the change of resistance and reactance of the field circuit of the machine used as an illustration, between the first and second papers. Could the authors state the basis of this change?

D-C Machine Stray-Load-Loss Tests

Discussion and author's closure of a paper by Victor Siegfried published on pages 1285–9 of volume 56, 1937, AIEE TRANSACTIONS (October 1937 issue of ELECTRICAL ENGINEERING) and presented for oral discussion at the electrical machinery session of the winter convention, New York, N. Y., January 27, 1938.

R. F. Franklin and T. M. Linville (General Electric Company, Schenectady, N. Y.): Stray-load losses of d-c machines are of particular interest to designers because by their reduction in value increased efficiency and decreased heating are obtained. Every effort, therefore, should be made to measure this loss as accurately as possible and to determine its manner of variation.

Designers have recognized the existence of stray-load loss for a number of years and many attempts have been made to evaluate its magnitude both by test and calculation. Unfortunately the nature of stray-load loss is such as to preclude its direct measurement. The usual method of measurement is to measure the total losses under load and from this measurement subtract all of the known losses which can be measured or calculated either directly or indirectly. This difference is called the *stray-load loss*. But some of the known losses cannot always be determined very accurately and vary in value from time to time. The errors thus introduced together with the inherent inaccuracies of testing methods, have lead to considerable difficulty in determining the stray-load loss.

Because of these difficulties, the AIEE Standards have devised a conventional segregated-loss method of evaluating these losses in which arbitrary methods of determining stray-load loss, brush-friction loss, brush-contact loss, and I^2R losses are given. These methods of determining these losses are, of course, to some degree in error, and attention was given to the possible error at the time the methods were devised. It is possible that with present better knowledge of these losses or possibly by some further investigation other methods could be devised that would give a more accurate determination of these losses in the majority of cases. It should be borne in mind, however, that the present method serves as a very practical and convenient method of determining individual losses which makes possible the approximate calculation of total losses without excessive cost to the trade.

On the other hand, it is also very desirable to have a more accurate method of determining these losses, even though the method may be more expensive and require more elaborate testing equipment. Such a method should prove of particular value to designers as the division of losses is of particular interest to them. It is probable that such a method would be too costly and impractical for general use. It would, however, afford a means of improving designs and furnishing data for a modification of the more convenient segregated-loss method which would make that method more accurate without increasing its cost and practicability. The booster-pump-back method described in these papers seems the most practical method yet devised. Its use is greatly handicapped by the requirement of duplicate units as it would be difficult to have machines calibrated for load loss available at all times. Nevertheless, an intensive study of this method in order to simplify the test procedure, find methods of increasing the accuracies of meter readings and reduce their number to a minimum and a determination of its limitations might be profitable. There are also certain inaccuracies in the determination of the various losses when using this method that should receive further study.

One of the most difficult losses to measure accurately is that of the brush losses. It is well established that the brush friction loss is sometimes reduced 50 per cent or more between no load and full load. Yet the brush friction loss is measured at no load and assumed to be the same under load. Because of this assumption the stray-load loss may actually measure negative at light values of load. It should, therefore, be recognized that under the present method of testing for stray-load loss that it contains a component of brush-friction even though this component may have a negative value.

Another loss that is difficult to measure is that of the brush-drop loss. Because of the uneven current distribution in the brush and the uncertainties of voltage measurements made on a moving commutator the actual brush-drop loss may be quite different from the loss measured. The difference between the two should be recognized as a component of stray-load loss.

A third uncertain loss measurement is that of the armature copper I^2R loss. This loss cannot be directly measured and so must be determined indirectly as accurately as possible. Since the magnitude of this loss is greatly influenced by the temperature of the armature winding, one of the problems is to accurately measure this temperature or else maintain it at the time the loss is measured. Either of these is difficult to accomplish and the inaccuracies introduced by the determination of this loss should also be recognized as a component of the stray-load loss.

The above discussion leads to the important conclusion that the stray-load loss cannot be measured without at the same time specifying how the other losses are to be determined. In those cases where the other losses cannot be accurately measured under the exact conditions of load at a given time, provision must be made to either measure them in a definite manner at no load under arbitrary conditions or to specify a definite manner for their calculation. In either case it should be recognized that any inaccuracies in the determination of any of the other losses will have an influence on the magnitude of the stray-load loss.

In analyzing the data given in the papers attention should be called to the distinction between the per cent stray-load-loss values given as compared to the one per cent stray-load loss specified in the AIEE Standards. The one per cent value is established in conjunction with the calculation of brush friction as a function of commutator speed, allowance of a definite value of volts brush drop and calculation of the armature I^2R loss at 75 degrees centigrade. The stray-load loss determined in the papers was not obtained in this manner. It is incorrect, therefore, to use the stray-load loss as measured in the papers as a basis for judging the conventional allowance of one per cent.

Commercially, only total losses are important and there should be little argument against the method of measuring the total losses described in the papers. Both papers recommend a booster for circulating current between the machines being tested. Unfortunately, the booster must carry the full current of the machines at a comparatively low voltage. Such a machine is not likely to be always available. It would be less expensive and more practical to adopt the conventional pump-back test as a sufficiently accurate determination of the total losses. This may be done entirely apart from a consideration of stray-load losses.

In conclusion, it appears that further study should be given to the measurement and calculation of the known as well as the stray-load losses. A better knowledge of these losses will not only be helpful to the designer in obtaining improved machines but will be helpful in increasing the accuracy of determining the total losses by the convenient segregated-loss method. The present papers show there is interest in the problem and have contributed valuable test data and presented improved methods of test. It is hoped further interest can be aroused in this subject so as to stimulate further investigation and progress.

E. W. Schilling (Michigan College of Mining and Technology, Houghton) and **R. J. W. Koopman** (University of Kansas, Lawrence): It is gratifying to know that at least one other party has answered the Institute's request that research work be started and papers presented on stray-load losses in d-c machines. Professor Siegfried has made tests using the so-called Kapp method and also using the Hutchinson test in which the two machines to be tested are direct connected and arranged in a pump-back connection using a booster to circulate the current. This last test is very similar to one of those used by us.

Referring to Professor Siegfried's figure 2, page 1286, ELECTRICAL ENGINEERING for October 1937 [AIEE TRANSACTIONS, volume 56] it is interesting to make a comparison of his method and our method of allocating the losses to the individual machines. Since we plot loss in watts as ordinates against average armature current as abscissae for the two machines, it is necessary to replot his curve *A* as shown in figure 1. Since his data plotted on logarithmic paper produces a straight line as shown in figure 2, the curve can be expressed by an equation of the form $L_a = kI_a^n$. The exponent is found to be 1.255. Now consider a point on his curve at 160 amperes. The distribution of current between the two machines is not given but for our purpose here we will consider $I_g = 75$ amperes and $I_m = 85$ amperes. The loss for one machine, at 75 amperes for example, will be

$$L_g = L_a \frac{I_g^n}{I_m^n + I_g^n} = 500 \frac{75^{1.255}}{85^{1.255} + 75^{1.255}} = 242 \text{ watts at 75 amperes}$$

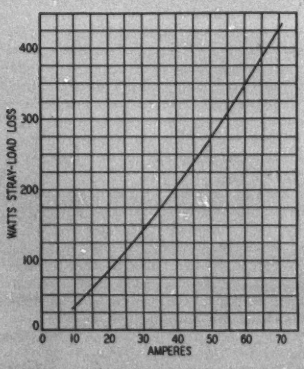
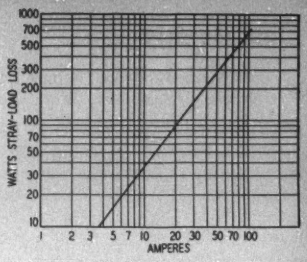


Figure 1. Curve A of Siegfried's figure 2 replotted to show average armature current for the two machines

Figure 2. Determination of the exponent n



An interesting portion of Professor Siegfried's paper is the application of paraffin to the commutator to reduce friction loss. We can readily agree that some such procedure would be desirable, provided that the contact drop would be unaffected. However, it is hard to believe that such would be the case. Test data taken on slip rings with and without paraffin should be made to determine whether or not this very valuable aid to the technique of making stray-load loss tests may be safely used under all conditions.

In our tests brush drop was not taken at standstill. Contact drop measured at standstill will not under all conditions be the same as when the machine is running. The difference may be so small that it can safely be neglected. Contact drop curves taken at standstill and at various speeds should be valuable in determining whether this simplification in the test procedure can be used without too great loss of accuracy.

In the last paragraph of "Test of Machines," page 1288 of Professor Siegfried's paper, it appears that the no-load loss was measured when the two machines were running as motors taking the same armature current. The booster was then included in the circuit and the load current increased. A final reading was then taken of the no-load loss. The exact procedure followed here is not perfectly clear. According to the test code, paragraph, 2.112, the core loss shall be taken "when excited to produce a voltage at the terminals corresponding to the calculated internal voltage." We presume that this was the purpose of the second reading. However, if such was the case, what was the purpose of the first reading?

Edward Hughes (Technical College, Brighton, England): The results discussed in this paper are very useful in showing the close agreement between the Kapp and the Hutchinson methods. Their value, however, would have been greatly enhanced if the author had analyzed the reliable data collected from the various tests in a manner that would indicate the fundamental relationships between the stray loss and the factors which affect its magnitude. In a paper published in the *Journal* of the Institution of Electrical Engineers, volume 63, 1924, pages 35–50, I investigated the effect of flux distortion on iron loss by measuring the iron loss in an armature with its winding on open circuit, the flux being distorted by passing current through a compensating winding. Figure 3 shows the results obtained at 2,000 rpm. Similar curves were obtained for speeds varying between 200 and 2,400 rpm. It was found that over this range of speed and for cross ampere-turns varying between zero and those corresponding to full-load and for field excitation ranging from zero to about 50 per cent above the normal excitation, the total iron

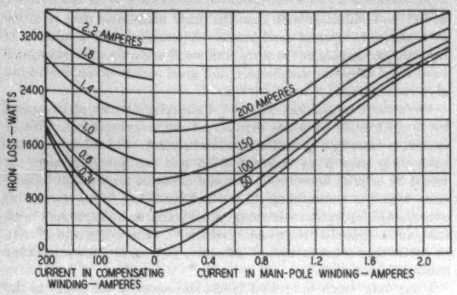


Figure 3

loss could be represented very closely by the following simple expression:

$$hf^{1.5}\{V_t(B_1^2 + B_3^2) + V_a B_a^2\}$$

where

h = a constant derived for undistorted flux
f = frequency in cycles per second
V_t = total volume of teeth
B_1 = mean flux density in tooth under strengthened pole tip
B_3 = ditto under pole tip at which the flux is reversed (if flux is not reversed, this term is omitted)
V_a = volume of armature core carrying flux
$B_a = \dfrac{\Phi + 2\Phi_c}{A}$
Φ = resultant flux per pole
Φ_c = cross flux (if any) re-entering pole shoe
A = sectional area per pole of magnetic circuit through armature core

The iron loss in armature teeth due to the flux of the commutating pole can be calculated from a similar formula.

The above expression has since been confirmed by R. G. Isaacs (*J.I.E.E.*, volume 69, page 1303). It is seen from the above expression that the stray iron loss is an integral part of the total iron loss. Consequently, if the stray loss is expressed as a separate quantity, it is impossible to relate it satisfactorily to the factors upon which it is dependent.

It is hardly necessary to emphasize that it is just as important to be able to predetermine the stray iron loss as it is to measure this loss after the machine has been constructed; and I would express the wish that the author should again analyze his results either to confirm the above expression or to suggest another that may fit in more satisfactorily with his own data.

T. H. Morgan (Worcester Polytechnic Institute, Worcester, Mass.): These papers are important and valuable in that they show that stray-load loss in d-c machines can be measured to a high degree of accuracy. The authors of both papers are to be complimented on their splendid painstaking work. Old and well-established methods are here applied to determine a loss which only recently has become recognized as one which cannot be ignored.

The results described in these papers indicate that we are well on our way in the matter of being able to definitely specify a simple straightforward method of determining stray-load loss in d-c machines. The load-back method is desirable because it gives a measurement of the loss with the machines under actual operating conditions. I am of the opinion that using boosters or other machines to supply certain losses separately and thus keep both machines under test in exactly similar conditions of load and field current is not necessary.

It is most desirable that a code method be as simple as possible without sacrificing the required degree of accuracy. It seems to me that these papers indicate that a test might be used in which one single voltage is applied to the machines operating in parallel on the same shaft with load conditions controlled by adjustment of the field currents. With this condition existing we would have the machines operating with slightly different armature currents and also with different field currents. The apportioning to each machine of the correct amount of its loss due to different armature currents can be conveniently and accurately taken care of by the method devised by Paul M. Narbutovskih for similar use in induction machines. If the law of variation of the stray-load loss as a function of saturation were sufficiently well established so that correct apportioning due to difference in field currents could be accomplished the problem would be solved and the whole matter of testing greatly simplified. The information given on this point in the papers would seem to indicate that for a given armature current the loss variation as a function of saturation might prove to be a very simple law throughout the range required for the test. Possibly the assumption of a straight line relationship would give the required degree of accuracy. Application of this law might be considerably simplified if one machine were over-excited to the same degree that the other was under-excited and the average excitation of the two similar machines used as the field current for this case. Further work along this line would be of great help in determining the accuracy of this proposal.

Coming back to the question of the test code I have never been able to understand a philosophy that says we will set up a code which will specify methods of testing for all the losses in a machine so that we may determine an accurate value of each, and then goes on to arbitrarily allot one loss as a fixed percentage of the input. I do not think that such procedure can be justified as being logical, scientific, or even practical, for in a matter of this kind practicality requires a fair degree of accuracy and not simply arbitrary action. It would seem that the authors of these papers have helped very materially by showing that it is possible to specify a definite method for the accurate measurement of stray-load loss in d-c machines.

L. E. Miller (Reliance Electric and Engineering Company, Cleveland, Ohio): I feel that Mr. Siegfried is to be complimented on the clearness of his paper. In view of the clearness and conciseness with which he has condensed the facts which might very easily cover many times the space of his paper, it seems like any discussion on the subject might be construed as near carping. I would like, however, to make some comments.

I believe that Mr. Siegfried has placed his finger upon the cause of considerable apparent inaccuracies which occur in many tests, when he attributed to the variability in the performance of the commutator. The very wide change in brush friction is very well brought out by Doctor S. W. Glass in his paper on "Measurement of Frictional Characteristics of Brushes," which was published in the July 1937 issue of *Iron and Steel*. Mr. Glass brings out in this article the possibility of a three-to-one change in brush friction for certain changes of temperature which are well within the range of a commutator temperature, and also a possibility of a variation as great as three-to-one occurring from sanding the commutator. He also brings out various rather wide ranges for various other phenomena which he classes as the effect of commutator poisons. In view of Doctor Glass' paper, I am forced to wonder as to whether it is not possible for paraffin, as mentioned by Mr. Siegfried, to cause certain inaccuracies which are not brought out into normal operation of the machine.

Siegfried also brings out the necessity of measuring the complete terminal to terminal drop, rather than assuming a constant value of brush contact drop. Presumably he makes this measurement while the machine is stationary. This brings up the question as to whether the stationary drop approaches any more closely the actual drop occurring while the machine is operating than the assumed value given under AIEE specifications. There is no doubt in my mind that the assumed value is inaccurate, but I question as to whether the stationary drop is not just as inaccurate.

Another point brought up in Mr. Siegfried's paper is the suggestion of leaving out series winding, which may be on the machine during

these tests. Certainly the use of such a series winding does effect the field strength, and does vary as the load varies. On the other hand, I think it is quite possible to get inaccurate results when producing the same number of ampere turns in the shunt fields as the series field would produce under the conditions simulated. We have found in actual test that ampere turns from the shunt field do not produce the same resultant flux as ampere turns produced by the series field. The reason for this is no doubt due to the location of the shunt in series field on the pole and the differences in leakage resulting therefrom.

Mr. Siegfried very carefully points out the hysteresis effect that is noticeable and causes a different result when changing from a higher field current to a lower field current from that which is obtained when changing from a lower field current to a higher field current. I would like to add that on test floor we have also noticed what appears to be a hysteresis effect from changing the armature current. This is particularly noticeable under weak field conditions, and is probably due to the distorting action of the armature on the main field. I would suggest that in making a test of this sort where accuracy is very essential, that the tester be warned always to change the armature current in the same direction just previous to making readings.

Apparently from the results obtained by Mr. Siegfried the stray load loss is much greater at the high speed of an adjustable-speed motor where the high speed is obtained by weakening the field. From the curve shown it appears to be six or seven times as great as the full field low speed condition when operating at two and one-half times the low speed, and perhaps is ten to fifteen times as great on a four or five-to-one speed range operating at high speed. It is theoretically correct that we should get a much higher stray load loss at weak field and high speed than we should at full field and low speed. However, I would like to bring up for what it is worth, the fact that in making dynamometer tests, attempting to determine the difference in losses between those shown by the conventional method and the actual losses which are obtained in a machine, we have found that we could not establish any fixed rule for variation in the stray-load losses. The results were quite erratic, sometimes showing a greater stray-load loss at full field and low speed, sometimes showing a greater stray-load loss at the weakened field and highest speed, and sometimes showing a greater stray-load loss at some in-between value. These tests were made a year or more ago, and since the commutators were not treated in any way but were simply used in the condition existing at the time the tests were made, it is possible that the difference in commutator losses more than accounted for this erratic behavior.

I note in Mr. Siegfried's paper that he does not say anything regarding the possibility of shaft current causing part of the stray-load loss. I would like to inquire as to whether, during his test, he found any evidence of shaft current existing.

In closing, I would like to inquire as to whether Mr. Siegfried found any material difference in percentage of stray-load losses on larger machines than were present on smaller machines. In other words, is the present neglect of stray-load losses on smaller machines justified, or do the facts of the case show that this should be taken into account on smaller machines as well as on larger machines?

R. E. Hellmund (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): It is not at all surprising that close agreement on load losses has been obtained with the various methods discussed in the papers on this subject. Although the current and voltage conditions in the two machines on test differ to some extent with the simpler methods, the differences are not large enough to affect the results materially. It is nevertheless very gratifying to have the results of these careful investigations presented here, as any of the methods proposed can now be used with considerable confidence.

I am firmly convinced that most of the previous unsatisfactory results were due to variations caused by brush friction and perhaps, to a less extent, to variations in contact resistance. Since brush friction decreases with load and temperature, it may well be that in some machines the difference between brush friction at no load and at full load will be greater than the other load losses thus resulting in a negative value of load losses. A machine with a number of brushes, and having at the same time small armature distortion, well subdivided armature conductors, and good commutation, is likely to give such results.

Professor Siegfried has eliminated the irregularities often caused by brush friction by using paraffin on the commutators. This of course, is entirely satisfactory when analyzing the load losses other than those caused by brush friction and contact resistance. It would be helpful, however, if he could continue his work and make tests with the commutator in normal condition, being careful to obtain stable operation and temperature conditions as applying to no load, and also similar tests under full load. Care would also have to be taken that other factors of influence, such as humidity, are kept reasonably constant.

I was very much interested in the statement in the paper to the effect that current conduction between the brush and commutator through the paraffin film takes place because of carbon particles embedded in the film. In a previous discussion at last winter's convention, I suggested the possibility of such embedded particles being a factor with the usual oxide film on the commutator even under normal conditions. I am therefore wondering whether Professor Siegfried has any evidence supporting this theory, such as microscopic inspection for example.

Victor Siegfried: The author is indeed gratified by the interest shown in this subject, as evidence by the amount and the character of the discussion. It is apparent that the matter of stray-load loss in d-c machines is by no means a closed issue, and that much remains to be learned concerning its variation with the factors upon which it depends. The author is fully aware that many of the points touched upon in this paper and in its companion by Professors Schilling and Koopman, and by the discussers, show the need for further investigation of particular factors affecting stray-load loss. It must be made clear, however, that the author is here concerned primarily with establishing *methods* for determining the loss, and only secondarily with investigating the nature of the loss, in so far as it affects the procedure of the tests. It is shown by these papers that the loss can be measured accurately by a convenient and simple method, and that it is no longer necessary or proper to adopt an arbitrary percentage value to be assigned to it.

In considering matters relating to stray-load loss, it is very important that it be defined clearly. The definition given in the Test Code for D-C Machines is not sufficiently general, as it specifically mentions losses to be included, but does not allow for all factors which should be considered as a part of stray load loss. Stray-load loss is the difference between total losses as they occur under load conditions and the values of the individually known losses determined separately from measurements made under no-load conditions. It is thus a residual loss which includes all variations of machine losses under load which cannot otherwise be accounted for by conventional methods. It is made up of numerous component losses which change in differing degrees with load, in such a way as to preclude establishing any one general law for it.

The author is in complete agreement with Professor Morgan and Messrs. Franklin and Linville that the load-back test (without boosters) is the most practical and simplest method to be used. Although the two machines do operate thereby at different field currents, a division of the loss can be made, if the excitation is assumed to be represented by the average of the two machines, with reasonably accurate results over the normal range of excitations necessary for this test. For apportioning the loss between machines carrying different armature currents, the graphical separation method, devised by Mr. Narbutovskih and alluded to by Professor Morgan (1. Morgan and Narbutovskih, ELECTRICAL ENGINEERING, volume 53, 1934 pages 286–90) was used in this paper. As Professors Schilling and Koopman show, the results agree with their method, which involves the determination of the exponent of the function representing the total losses. It does not always follow that the exponent is constant over the entire range of currents in the machines, so that this method suffers from the limitation that the ex-

ponent must be determined in the range for which the separation is desired. The difference in methods is principally that between graphical and analytical approaches, as both perform the same operations upon the function; the choice is thus largely one of personal preference.

Mr. Hellmund points out the possibility of a decrease in brush friction with increasing values of load, and also that negative values of stray load loss may thus be indicated in certain instances. Such results must be interpreted in the light of the general definition of the loss, and in no way be allowed to reflect on the validity of the test. It was with full appreciation of the extreme variability of brush performance that the expedient of paraffining the commutator was adopted in making these tests, and it must be admitted that the results do not include any consideration of the possible decrease in this so-called constant no-load loss. Such procedure was permissible under the Test Code definition of stray load loss, which did not allow for any such variation. The comparison of methods as presented in the paper, and the general relations of stray load loss to operating factors, are in no way rendered less valid by this procedure, but are in some measure enhanced by the removal of the one factor which might otherwise mask the true picture of the more important components. The author's mental concept of the mechanism of commutator-brush conduction apparently agrees with that of Mr. Hellmund, although no effort has been made to substantiate it by microscopic examination of the paraffin film. The only evidence that can be offered is the blackening of the wax film either by carbon particles from the brushes or by carbonization of the paraffin itself.

Messrs. Franklin and Linville have very capably pointed out the possible inaccuracies involved in making the separation of the total losses under load into known and stray-load losses whatever the method for determining them. Again the matter is one of definition, and final efficiencies should have correct values so long as the procedure is consistent. They also state that it is well established that the brush-friction loss is sometimes reduced by half between no-load and full-load. While this is quite conceivable, it would be helpful to a fuller appreciation of the part played by brush friction in the total losses to have further investigation of this factor presented in published form. The available information on this point is quite limited, and it may be that what is considered as common knowledge among manufacturers is as yet unreported in a form to make it available to independent investigators. The author here makes the plea that the manufacturers, whose designers are the ones to benefit most by the full discussion of this subject, themselves undertake and publish the results of careful and open-minded investigations. The investigation of the known as well as the stray-load losses would certainly aid in bringing the whole consideration of d-c machine efficiencies up-to-date and in line with the growing importance of the d-c machine.

The percentage values presented in the papers are not strictly in accordance with a general definition of stray load loss, in that they do not account for certain variations in "constant" losses which might work for the reduction of the total stray load loss. These "known" losses were subtracted from measured total losses exactly as they occurred at the time of the test. The values are at least consistent with the original Test Code definition, and form a valid basis for comparing machines within a certain size class. The author himself would dislike to have these figures or any other figure so presented used as an argument in favor of the one per cent rule. Any agreement of the measured stray load loss with this one per cent figure must be taken as accidental, as the only satisfactory means of arriving at stray load loss is to measure it.

It has been proposed from time to time that a measurement of stray-load loss might be had by determining the increase in power needed to drive the rotor of a machine when it is short-circuited and sufficient excitation applied to circulate full-load current in the armature. Curve *E* of figure 3 of the paper shows the trend as the excitation is reduced, with a stray load loss 50 per cent greater at 28 per cent excitation than at normal excitation. Subsequent tests of the same machine by this short-circuit method show a loss of 300 watts, or practically double that for normal operating conditions. The conclusion is inescapable that this method has no place in the array of possible methods for determining stray-load loss.

This discussion does bring out the need for a more complete treatment of stray-load loss in the Proposed Test Code, so as to make the definitions general and correct, and also to specify rather definitely what procedures are to be followed in determining stray-load loss by measurement.

The discussion offered by Mr. Miller is very much appreciated, as it amplifies some points given only brief mention in the paper. The wide variability in performance of the commutator is easily demonstrated by almost any operation that is performed upon it, or by any conditions to which it is subjected. The continual fluctuation of armature current under no-load conditions is indicative of this variation, and sanding of the commutator produces notable and long-lasting increases in loss, with accompanying heating effects. Likewise, paraffining produces a marked decrease in loss, and it was observed in some instances that the total rotational loss was decreased by as much as 20 per cent. This represents a considerable decrease in actual power for any machine, and the cooler operation of the commutator at no-load was very apparent. The paper by Doctor Glass, which was not available at the time of writing the paper, is a very fine treatment of the subject and is worthy of considerable study.

As to the terminal-to-terminal drop, it was not stated just how this was obtained, and the conclusion that it was measured while stationary is not surprising. However, the armature was actually rotated slowly by hand so as to procure average sliding contact conditions. It has been the author's experience that this represents the running contact conditions with sufficient accuracy that it is far preferable to measuring the contact drop at full speed. Although this is not in accordance with code provisions, the intent was to measure the drops as they actually occurred at the time of the test, so as to measure the actual stray-load loss.

The series winding was left out for purposes of the comparative tests for loss with different methods where the armature current conditions could not possibly be duplicated, but the commutating winding was included at all times. This established the magnetization as being entirely from an independent source and not dependent on the variable armature currents. That the ampere-turns of shunt and series fields are not of equal effect in producing flux is open to little question. It may be possible that, once the validity of the test method has been established, the series winding should be left in so as to give its full effect as under operating conditions. It is interesting to note that this will require reversing the series coil on the machine which serves as the generator of load-back couplet.

The experience with regard to hysteresis effect when changing armature current is well included at this point. It was mentioned briefly in the paper that this same effect was present in the machines tested, particularly when the low excitation run was made. It is felt that the effect is of minor importance at normal saturations of the machine, but is well worth keeping in mind as it explains some manipulative difficulties that are otherwise surprising. As to shaft currents, no attempt was made to determine the presence of shaft currents, or in general to separate out the relatively smaller components of the stray-load loss. The size of the machines tested seems wholly unrelated to the amount of the loss measured, and it is the author's feeling that even on small machines, where efficiency guarantees are of any importance at all, some tests must be made to measure the actual value of that loss.

A detail of test procedure has been questioned by Professors Schilling and Koopman, and it is sufficient to say that both first and last readings of no-load loss were taken in accordance with standard procedure, the duplication being made to be certain of no major change in rotational loss during the test. Any difference of minor order was either prorated according to the time elapsed, or taken as an average of the two readings.

The author is very glad to have the discussion from Mr. Hughes, of Brighton, England. He raises a question on a point which is often forgotten in the consideration of stray-load loss; namely, the original source of what is included in this rather comprehensive term. Certainly a sizeable portion of the stray-load loss is due to a change in the total iron loss of the machine with the increase in load current. It does not seem possible, however, to relate the stray iron loss to flux conditions when it is practically impossible to separate the loss into

the many components which of necessity are included in it. The test suggested by Mr. Hughes is one which would appear to have some promise for getting at the iron loss component, provided the machine in which one is interested has a compensating winding. The analytical expression for total iron loss should be helpful in considering the problem from this rather fresh point of view.

Too often the original source of the approximate methods of dealing with anything become so obscure that the very obscurity tends to strengthen the belief that those methods are exact, and it remains for one from afar to break down the time-honored acceptance. It is this desire, academic though it may be, to bring a fresh consideration of the stray-load loss to the d-c machine which prompted the author to undertake this work originally, and it is his hope that further progress can be made until the accurate treatment of the d-c machine is as well established as that for any other, particularly in view of the present major trend to d-c machines for large mill drives where certain inherent characteristics make them indispensable.

Unsymmetrical Short Circuits on Water-Wheel Generators Under Capacitive Loading

Discussion and author's closure of a paper by C. F. Wagner published on pages 1385–95 of volume 56, 1937, AIEE TRANSACTIONS (November 1937 issue of ELECTRICAL ENGINEERING) and presented for oral discussion at the electrical machinery session of the winter convention, New York, N. Y., January 27, 1938.

C. Concordia (General Electric Company, Schenectady, N. Y.): There are two points which should be brought out in connection with this paper. First, because of the test method, i. e., the application of the capacitor or reactor load at the moment of short circuit, the transients are different from those associated with an actual fault on a system in which the capacitance or other load is continuously in the circuit. Also, due to generator regulation, even the steady state overvoltages observed are not the same as those obtained with similar permanent loads, the apparent overvoltages being high for capacitance load and low for inductance load. Near the point of third-harmonic resonance this difference may be about 30 per cent, but can of course easily be corrected by calculation. In spite of these differences, the test overvoltages are undoubtedly qualitatively the same as those which would have been obtained in tests simulating more exactly the condition of an actual fault.

Second, it should be emphasized that the ratio x_q''/x_d'', upon which the overvoltages due to line-to-line faults largely depend, is not simply dependent upon whether or not the amortisseur end rings are connected between poles, as might be inferred from the paper. In the machine used in Mr. Wagner's tests, an unconnected damper winding gave a relatively large ratio, but as the machine size, in particular the relative axial length, is increased the difference between unconnected and connected damper windings becomes smaller. Thus, for large low-speed water-wheel generators, unconnected damper windings may be much more effective than would be indicated by tests on a small machine. Moreover, the amortisseur design may have considerable effect on the ratio x_q''/x_d'' aside from the connection between poles. Finally, the many other functions [see "Overvoltages Caused by Unbalanced Short Circuits" (Effect of Amortisseur Windings), by Edith Clarke, C. N. Weygandt, C. Concordia] of amortisseur windings should be considered in every application.

Because of these factors, the electrical performance characteristics of an amortisseur can be more accurately described in terms of the ratio x_q''/x_d'' than in terms of whether it is connected or unconnected between poles.

W. V. Lyon (Massachusetts Institute of Technology, Cambridge): This comprehensive analysis of Mr. Wagner's is particularly interesting to me. In 1926 Rene Brosens working under my direction obtained oscillograms of the open-phase potential when a line-to-line short circuit occurs on a three-phase generator delivering a condensive load. As a generator he used a wound-rotor induction motor having a leakage coefficient of 0.046, and consequently the ratio x_q/x_d' was about 20. For this reason Brosens obtained a much higher open-circuit potential than Mr. Wagner. Brosens noted a peak potential of about 18 times normal peak line-to-line potential. By applying the simplified theory proposed by Boucherot in 1911 which neglects resistance and is consequently similar to the "constant flux linkage" theory of Doherty, Brosens checked the peak values of potential within about 10 or 15 per cent. He made no analysis of wave form. A brief report of Brosen's work was sent to a few operating companies calling their attention to the possible danger of overpotentials with these conditions of operation. Apparently at that time the results were considered of only theoretical importance, and so far as I know no attention was paid to the warning.

Fundamentally the excessive steady-state potential on the open phase is due to the difference in the transient reactances in the two axes. Even with a salient-pole machine it is theoretically possible to have a damper winding for which these reactances are equal.

C. F. Wagner: Mr. Concordia is quite right in his point that the transients resulting by suddenly applying a short circuit across two terminals and a capacitor across the sound phase simultaneously will give a transient different than if the machine had been loaded before the application of the short circuit. I had made tests (see figure 11) with the capacitor connected before this short circuit and had come to the conclusion, however, that the difference is rather small. The general question of the effect of load regulation is discussed to some extent in my paper. It likewise will make a difference. As a matter of fact it is possible to enumerate a host of factors that make a greater difference (and a much greater difference) than the factors of whether this capacitor had been connected before the fault or whether the regulation had been included properly. In practice it rarely occurs that the ideal conditions of an unloaded line to which a short circuit is applied are satisfied. Usually the machine under consideration is feeding power over a line to the end of which other synchronous machines are connected. These machines will usually have a damper winding or its equivalent. Upon the inception of an unbalanced fault, abnormally high voltages may be produced but if the breaker at the receiving end of the line opens first, then a condition is satisfied under which much higher voltages may be produced. But in the transition to this, the important condition, note that an intermediate circuit condition was passed through. The transients during the beginning of this final circuit condition would in all probability be entirely different than if a similar unbalanced fault was applied to the unloaded machine, for example, while it is connected to the capacitance of the line.

Mr. Concordia also infers that many of these conditions can be calculated easily. It must be remembered that the resonance conditions are the important points. But for this condition the armature resistance is very important in determining the maximum voltage. A method of analysis which will predict the maximum voltages must be capable of introducing the effect of resistance. Further, in the absence of a knowledge of these resistances it is impossible to predict the maximum voltages. As shown in my paper the resistance varies with the frequency and while these data were obtained for a machine without damper windings a similar relation should apply for machines with damper windings. In this case the current distribution between bars and within the bars will vary and affect the resistance. A quantitative analysis should therefore include this factor quantitatively and must apply for the resonance points. A comparison of figures 13 (*b*) and (*c*) of my paper gives some idea of the effect of armature resistance near a resonance point.

With regard to Mr. Concordia's second point that the inference might be taken from my paper that the effect of damper windings is simply dependent upon whether the damper winding is connected or not connected, I wish to call his attention to my statement near the end of my discussion of this subject (page 1391) which reads: "In any case figures 8*d* and 8*h* show that dangerously high voltages

can be attained with this kind of damper unless precautions are taken to insure that the ratio x_q''/x_d'' is made more nearly equal to unity." With nonconnected windings much can be done by properly locating the end bars to reduce this ratio considerably.

But after all most of these points are more of academic than of practical importance. The analysis of this subject either by the method presented by Clarke, Weygandt, and Concordia or by the method presented by myself indicates that the general factors affecting the problem are pretty well understood. The practical solution appears to be to install non-connected damper windings with as low values of x_q''/x_d'' as is practical to obtain.

Professor Lyon's discussion is very interesting. It is unfortunate that Brosens did not extend his analysis at the time to salient-pole machines. It is quite probable that his theories in this case would have received a more favorable reception.

Stray-Load Losses of D-C Machines

Discussion and authors' closure of a paper by E. W. Schilling and R. W. Koopman published on pages 1487–91 of volume 56, 1937, AIEE TRANSACTIONS (December 1937 issue of ELECTRICAL ENGINEERING) and presented for oral discussion at the electrical machinery session of the winter convention, New York, N. Y., January 27, 1938.

R. F. Franklin and T. M. Linville: For discussion, see page 401.

T. H. Morgan: For discussion, see page 403.

R. E. Hellmund: For discussion, see page 404.

Victor Siegfried (Worcester Polytechnic Institute, Worcester, Mass.): This paper is a valuable contribution in that it gives further proof of the need for a renewed consideration of the matter of stray load loss in d-c machines. The fact that a test method for determining these losses is available in which confidence can be placed is demonstrated by the results that Schilling and Koopman present. The writer is in whole-hearted agreement with their conclusion that the loss must be measured rather than assumed to have some arbitrary percentage value.

The authors do not state the ratings of the machines used, nor whether series or commutating windings were in use during the tests. This information would be helpful in interpreting their results. Assuming, however, that the machines are rated at 110 volts, and taking rated current as 16.85 amperes, it would appear that rated full-load input is 1,854 watts. Reading from curve *B* of figure 10, a value for stray load loss of 35.5 watts per machine, the loss is thus 1.91 per cent of full load input. Such a figure shows that the loss is one which cannot be neglected even for small machines, and that the one per cent rule of the Standards is wholly inadequate to take account of this loss.

Schilling and Koopman are to be congratulated on the consistency of points on the curves presented in the paper. This shows careful work in the conduct of the tests, and further demonstrates that stray-load loss is actually measurable. Too long has the feeling been expressed that stray-load loss is not measurable. Their paper does present one method for determining it with results checked by an independent method, as shown in their figure 7. The experience of this writer is much the same—that stray-load loss can be measured, that consistent results are obtainable, and that independent methods give practically identical results.

E. W. Schilling and R. W. Koopman: In his discussion Professor Siegfried raises the questions of rating, and connection of the series and commutating-pole windings. The machines were rated two horsepower, and the commutating-pole windings were connected in the usual manner. The series fields, however, were not used.

The writers are greatly pleased by the interest in this paper shown by engineers of the larger manufacturing companies. Messrs. Hellmund, Franklin, and Linville point out that brush friction changes between no load and full load. In order to measure bearing and brush friction at conditions as near to actual load conditions as possible the machines were run until constant temperatures were reached before loss measurements were made, and friction loss was measured at no load immediately thereafter. Thus brush friction was measured at very nearly the same temperature, commutator surface conditions, and humidity as prevailed under load. As to the question of reduction in brush friction due to increase in current which is raised by Messrs. Franklin and Linville we have no data; however, it is evident that the change was not great enough to cause the low values of load-loss to swing negative. The writers admit that it is hard to determine accurately the brush-drop loss; however, the values obtained at rated current checked closely the conventional two volts. At any rate, by making allowance for increase in brush drop with increase in current, more accurate data for stray-load-loss were obtained than would have been obtained had the conventional value been used.

If armature I^2R loss had been calculated at the conventional temperature of 75 degrees centigrade and brush drop taken as two volts, some of the lower values for stray-load-loss would have certainly been negative. This would have been logical procedure had one definition of load loss been adopted; however, the writers attempted to adhere to the definition for stray losses given in the table under paragraph 2.105 of American Standards for Rotating Electrical Machinery, *C*50.

The writers do not feel that they have presented adequate data to question the magnitude of the present percentage taken for stray-load loss, but they do believe that they have presented sufficient evidence to show that the use of a constant factor for all conditions of speed and field is quite inadequate.

Switching Surges With Transformer Load-Ratio Control Contactors

Discussion of a paper by L. F. Blume and L. V. Bewley published on pages 1464–75 of volume 56, 1937, AIEE TRANSACTIONS (December 1937 issue of ELECTRICAL ENGINEERING) and presented for oral discussion at the power transmission session of the winter convention, New York, N. Y., January 27, 1938.

R. C. Van Sickle (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): The data presented in this paper are of interest to those concerned with switching surges in general, as mentioned by the authors, so a few remarks on their relation to other available circuit-breaker data are pertinent. It is particularly necessary to point out that although the phenomena in high-voltage circuit breakers are similar to that presented here, the magnitudes are much different and in particular the voltage surges are much smaller.

The load-ratio control switches were tested on power sources of 1,000 volts, 20 amperes alternating current and 125 volts, 25 amperes direct current. The speed of opening was relatively fast and currents of 15 amperes were unstable and extinguished without waiting for the normal current zero. The overvoltages produced by them were enormous. By the interruption of direct currents, overvoltages of 67 times normal were encountered and of alternating currents overvoltages of 18 times normal. Such voltages on high-voltage lines would be disastrous so it is fortunate that certain limiting influences exist.

The maximum dielectric strength between contacts of a high-voltage breaker is relatively less than that of contactors. Moreover the increase in the gap between contacts during the period of current zero is also relatively smaller. Consequently, if the arc is interrupted

before a normal current zero, by one of the usual forms of high-voltage circuit breakers, the maximum voltage which can be produced is limited by the dielectric strength of the arc path to a magnitude which does not damage other apparatus. A paper "Breaker Performance Studies by Cathode Ray Oscillograms" presented before the Institute in 1935[1] contains an illustration, figure 4, which shows an excellent example of this voltage phenomena which occurred during the interruption of 20-kv, six amperes by a high-voltage breaker. The arc was unstable and restruck about 30 times before a current zero. However, the contacts had not separated sufficiently to enable the breaker to withstand the recovery voltage at this current zero so the arc restruck and continued as an unstable restriking arc until the next current zero. During this time the current flowed through the breaker as a series of impulses with a time interval between them less than 0.0001 second. On the magnetic oscillogram it looks like a normal half-cycle of current during an arcing period. Even with this extremely unstable arc, the maximum overvoltage produced by the circuit breaker was about ten per cent of the normal crest value of voltage.

The effect of having a relatively higher dielectric strength is shown in figure 6 of the same paper. It is a cathode-ray oscillogram of the interruption of a 70-kv 20-ampere circuit by an experimental 287-kv high-speed breaker. In this case, the arc is unstable for approximately two-thirds of a cycle but due to asymmetry of the current two normal current zeros occur in this period and the arc restrikes after the first one. The rapid speed of operation and high dielectric strength of the breaker produce overvoltages approximately 3.5 times the normal peak of the 70 kv applied. However, a pole of a 287-kv breaker must open 87 per cent of 287 kv which is a voltage having a crest value equal to the overvoltages obtained on this test.

The paper by Attwood, Dow and Krausnick on "Reignition of Metallic A-C Arcs in Air" presented before the Institute in 1931[2] contains similar material and was based on arcs in low-voltage circuits. However, the overvoltages obtained were not as high as those given in this paper because the arcs were produced between stationary copper plates eight inches square and three-fourths inch apart. Some of these arcs became unstable and extinguished before the normal current zero. However, the arc terminals were not being separated rapidly and consequently the maximum voltages produced by the current rupture were limited to about the normal crest voltage either by a glow discharge or by a complete dielectric breakdown between electrodes. On the basis of the oscillograms in these papers it is reasonably safe to conclude that unstable arcs in high-voltage circuit breakers do not produce as great overvoltages as are shown in the paper under discussion and that they probably are limited to considerably less than twice the normal voltage crest.

The maximum value of the current at which the arc becomes unstable is given as five amperes for the a-c tests. This is higher than the 0.6 amperes for the arcs between stationary copper plates where conditions were less favorable for arc extinction. However, in the 70-kv 20-ampere circuit previously referred to, where conditions were more favorable for arc extinction, the arc was unstable through the small loop of an asymmetrical wave during which the magnetic oscillogram indicated a smooth loop with a crest value of 19.2 amperes.

The interruption of a 44-kv 330-ampere short circuit with the current becoming unstable at 11 amperes is shown in a paper, "Arc Extinction Phenomena in High Voltage Circuit Breakers" presented before the Institute in 1933, figure 6.[3] These data indicate that the current at which the arc can suddenly extinguish is a function of the effectiveness of the deionizing activity and the rate of current decrease.

The maximum value of direct current at which the arc extinguished abruptly is given as 15 amperes on page 1464 and as 20 amperes on page 1470.

The reported erratic recovery of dielectric strength may be due in part to the interpretation of the data. It was assumed, as given in the conclusion, that "Restriking was so abrupt as to be practically instantaneous and was followed by an immediate dielectric recovery." The discharge of a current through the arc space during a restrike requires the ionization of the arc path and, although the dielectric strength of the path does not fall to zero, it must be appreciably reduced. The magnitude of the ionization is indicated by the oscillograms which show that these restrikes pass the equivalent of a steady current of several amperes. Consequently, the assumption that the envelope of the restriking voltage is the curve of dielectric recovery against time and that it gives the dielectric strength at any instant is not justified. The first figure referred to in this discussion illustrates this point also. The recovery voltage builds up to about 25 per cent of the normal voltage crest following the relatively long deionizing period at the first current zero. (At the left of the oscillogram.) After the restrike, the value of voltage at which the arc restrikes is only about eight per cent of the normal voltage crest. The ionization produced by the restrike has definitely reduced the dielectric strength.

The curve of the recovery of dielectric strength as a function of time should be a broken curve with an abrupt drop at each restrike and with the following rise indicating the recovery. However, due to the various factors controlling the deionization, the recovery will still be erratic but not in the manner indicated in this paper.

REFERENCES

1. ELECTRICAL ENGINEERING, volume 54, 1935, pages 178–84.
2. AIEE TRANSACTIONS, volume 50, 1931, number 3, pages 864–8.
3. AIEE TRANSACTIONS, volume 52, 1933, pages 850–60.

D. C. Prince (General Electric Company, Philadelphia, Pa.): The investigations and data obtained by these authors disclose some very interesting phenomena applicable to currents and voltages of the order of magnitude of load ratio control, the field in which they have worked. In endeavoring to extend the reasoning to other fields, particularly the circuit-breaker field, a certain amount of caution must be observed. Arc phenomena of the nature of those which they are investigating in general are very different if the scale is changed. It is therefore not in general safe to assume that overvoltages would be multiplied by the same amount if different current values were used, or that they would be multiplied by the same amount if different voltage values were used.

For both higher currents and voltages, circuit-breaker experience over a considerable period of years shows that overvoltages, where they occur, are of relatively small magnitude. In the range covered by the authors however these phenomena are very interesting and have counterparts in other fields such as mercury-arc-rectifier arc backs, etc.

R. D. Evans and **A. C. Monteith** (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): It is significant that three of the papers presented at this session deal with switching transients. This is indicative of an increasing interest in the problem not only from the theoretical point of view but particularly from the practical standpoint because of problems actually encountered in the operation of power systems. It should, however, be clearly recognized that the paper by Messrs. Blume and Bewley deals with a very special type of transient problem. These remarks are not to be construed as a criticism of the paper because the authors have indicated this fact in the title and have stated it in the early part of their paper.

Concerning the authors' investigation, we would like to comment on certain specific points. In reviewing the paper we find no mention of the characteristics of the source, a factor which we believe to be of importance. If the abrupt forcing of current zero takes place there will be an oscillation on the source side as well as on the load side of the circuit-interrupting device and the voltage appearing across the device will be the vector sum of the oscillating voltages appearing on both sides.

The authors have divided the recovery voltage problem into three parts: first, the normal-frequency component; second, the high-frequency component dependent on the capacitor voltage; and, third, the high-frequency component depending on the reactor current. Our paper "The Determination of Recovery Voltage by Analytical and A-C Calculating Board Methods," presented at the

1937 summer convention, dealt with this case and the results for interruption at other than current zero were discussed in connection with figure 25 of that paper. In considering these factors it is believed that the third is only of importance in dealing with relatively low current values, such as discussed by the authors. In a normal power circuit with typical values of fault current, it is believed the third factor becomes less significant, especially on the higher-voltage circuits.

The authors have inferred the same "dielectric-recovery curve" whether there is or is not restriking. The shape of the dielectric-recovery curve will be materially modified when restriking takes place and the shape will be dependent upon the number of restrikes. In high-voltage circuit breakers it will depend on the contact separation. Therefore, the phenomenon is not as simple as indicated in figures 6, 7, and 8.

Production of high-frequency transients on a large scale is not to be expected on power systems with conventional types of current interrupters from the factor of the forcing of the current zero as described by Blume and Bewley. Instead, it is our opinion that such voltage, if encountered, will be due to the successive re-establishment of the arc path at such intervals as to produce cumulative oscillations. In this connection it should be pointed out that the process of producing cumulative oscillations requires certain rather definite relations between the system recovery-voltage time curves and the insulation recovery-time curves to make it possible. If the shapes of these curves differ from that which is required, the oscillations do not become cumulative and the voltages will be limited to about the value corresponding to a simple arc suppression or to that of one restrike. It is because of this difficulty in setting up the essential conditions for cumulative oscillations that has made their probability so small that they are rarely encountered.

Summarizing, it is our opinion that if high voltages due to switching transients on main power circuits are to be encountered they will take place principally through the mechanism of restriking just described. Furthermore, the mechanism of producing overvoltages by the sudden forcing of current zero appears to be a factor of small importance on high-voltage apparatus and circuits but of increasing importance as the voltage is reduced until it becomes a major factor in the special type of problems to which the authors have limited their investigation.

J. D. Cobine (Harvard Graduate School of Engineering, Cambridge, Mass.): The authors are to be commended for their instructive presentation of the nature of the voltage appearing across an impedance when its current is interrupted by a switch.

The curves of figures 6 and 7 assume that the duration of current subsequent to a restrike is zero and there is no change in the dielectric recovery curve, while the oscillograms of figures 9, 10, and 11 show that the voltage falls at approximately a uniform rate for a measurable interval of time during which current is apparently flowing. Now if an arc current flows after restrike the dielectric strength of the gap has obviously been reduced to a low value and an entirely new dielectric recovery curve must be plotted starting from the time the new current flow is interrupted. Thus in figures 6 and 7 a new dielectric recovery curve must be drawn for each restrike. These dielectric recovery curves will be different from the first because of two important factors, namely, the current of the new arc will have changed and the length of the gap at the time of its interruption is different. The new arc current will be less than the old and therefore the dielectric recovery will increase at a more rapid rate than before. Lengthening of the gap will also raise the recovery voltage curve. Of course, if the restrike current is very small and of short duration there will be little change in dielectric recovery. It would be of great value if the authors could give some values of current that are typical of the restrikes presented.

The shapes of the experimental curves of dielectric recovery, figure 11, are quite interesting, but somewhat obscure as to details. What is the difference between the several curves for the same shunt capacitance? Was the initially interrupted current the same in each case? If so, what was its value?

It may be that the erratic behavior of the restriking voltage of the switch is due to the presence on the contacts of impurities having low work-functions. These impurities would also be vaporized into the arc column and by their low ionization potentials lower the reignition potential. Some research of the writer (ELECTRICAL ENGINEERING, volume 53, 1934, page 1081) has brought out the marked effect of impurities in lowering the reignition voltage of a short arc. Small amounts of these impurities were found to produce random variations in the reignition voltage. It is obviously very difficult to have a commercial device free of impurities so that the switch was probably thoroughly contaminated.

Protection Features for the Joint Use of Wood Poles

Discussion and authors' closure of a paper by J. O'R. Coleman and A. H. Schirmer published on pages 131–40 of this volume (March section) and presented for oral discussion at the power transmission session of the winter convention, New York, N. Y., January 27, 1938.

Sidney Withington (New York, New Haven and Hartford Railroad Company, New Haven, Conn.): This paper indicates the great advantage of broad-minded co-operation between power companies and communication interests, permitting the solution on a purely rational and engineering basis of problems which may be of somewhat controversial nature. Both classes of utilities, the electrical engineering profession, and the public generally are to be congratulated on such co-operation.

The public utilities commission of the State of Connecticut, 1922, stimulated among the utilities in the state the compilation of rules and specifications governing joint wood-pole-line construction carrying power circuits of more than 5,000 volts, and communication circuits. These rules provided for construction on a basis mutually agreeable to all interests concerned and saved both power companies and communication companies a very considerable amount of money in duplicate construction, which would have been necessary if each class of public-service companies had been obliged to construct its pole lines independently of the other. That was one of the earliest instances of such joint action among the utilities interested, and was a notable example of successful co-operative effort in the solution on a rational basis, of problems which might otherwise have continued to be troublesome and expensive to all concerned. It is indeed a source of gratification that such co-operation is being continued.

H. A. Dambly (Philadelphia Electric Company, Philadelphia, Pa.): This paper marks an important advance in the co-ordination of electric power and telephone systems. It was early recognized that for two services which so generally supply the same customers, design based on keeping the two systems widely separated was not practical in the long run, and that any solution which did not permit both systems to occupy the same general area and the same streets and highways was unsound from the long point of view. Joint use as compared to separate lines for many situations is a further step in the recognition of this principle. Further, the advantages of joint use which have been conclusively demonstrated over many years in the lower voltage field clearly indicated the necessity for developing means to permit similar operation at the higher voltages. This paper presents a much needed answer to these situations.

The paper is particularly timely in view of the rapidly increasing demands for electric service which in turn have brought many companies face to face with the problem of raising primary distribution voltages in order to meet these demands. Many of these systems are now operating on a joint use basis at 5,000 volts or less, and the necessary pole plant investment to accommodate both systems has been made. Under these conditions the need for suitable design features which will permit continuance of satisfactory joint operation at the higher voltages is evident.

By co-operative arrangement between the operating companies

involved and the joint subcommittee on development and research of the Edison Electric Institute and the Bell System, the protective features outlined in this paper have already been worked out for a number of specific situations throughout the country, and it is believed that reasonable solutions can be reached in any specific situation.

In discussing separate lines versus joint lines, the statement is made that in rural and thinly settled areas it has been generally practicable and desirable to construct separate lines. It is recognized that types of construction widely different from normal span lengths may affect economies. However, it seems to me that in these areas one of the principal advantages of joint use, namely, the saving in avoided investment in poles with consequent saving in annual charges may be obtainable, particularly if planning is done on a broad forward-looking basis. Economies are needed to minimize the cost of both services to these rural customers. While the application of the protective measures in these areas involves somewhat different problems than in suburban and urban areas, the methods outlined in the paper should be applicable in these rural areas.

A. H. Schirmer: No one will question Mr. Dambly's statement that every reasonable economy should be practiced to minimize the cost of power and telephone service to rural customers. However, experience to date in studying specific situations, particularly those involving the long-span type of construction which has recently been used by most power companies in rural areas, indicates that, in general, there is no economy in joint use of lines in such areas, even from the structural standpoint alone. In other words, rural telephone lines on separate poles can, in general, be maintained at an annual charge less than the yearly cost of placing such circuits on jointly used poles. Furthermore, the inductive co-ordination problem in rural areas is frequently a difficult one even where separate power and telephone lines are used, and this difficulty may be definitely increased where both the power and telephone circuits are on common poles.

Lightning Strength of Wood in Power Transmission Structures

Discussion and authors' closure of a paper by Philip Sporn and J. T. Lusignan, Jr., presented at the power transmission session of the winter convention, New York, N. Y., January 27, 1938, and published on pages 91–101 of this volume (February section).

F. E. Andrews (Public Service Company of Northern Illinois, Chicago, Ill.): It is desired to emphasize conclusion 8 in the paper to the effect that the data presented add greatly to the knowledge of the impulse insulating property of wood in transmission structures. This paper appears to provide a basis very much more satisfactory than any information heretofore available on the design of wood-pole transmission and line structures to withstand impulse voltages.

This discussion is presented from the point of view of operating experience of 33-kv wood-pole transmission lines, using pin-type insulators without ground wire, with nine feet of wood between phases and the equivalent in insulating value from line to ground of 800 to 1,000 kv minimum on the basis of information in the paper (from figure 12). This operating experience indicates very greatly improved operation, that is, reduction in line tripouts, with this construction in comparison with conventional construction, that is, construction using steel crossarm braces and without impulse insulation in the guys.

Many cases have been noted where lightning has discharged over a structure without power follow or line interruption, the location of such cases being indicated by splinters on the poles or crossarms. In the cases where power follow has caused tripouts this has usually been found to be due to an arc between phases and in a number of instances, as indicated by burns on the conductor, this has taken place through air in the span away from the pole with minimum phase to phase distance of 7.3 feet. This experience indicates that there is no practical spacing with 33-kv single-pole construction at which power follow will not occasionally occur, although the wide spacing appears to materially decrease the susceptibility to power follow by comparison with results obtained with conventional construction.

In order to have a complete answer to the problem of lightning interruptions to lines of this type so that performance can be definitely estimated or predicted, it seems necessary to obtain in addition to lightning flashover data of the character covered by this paper, data on factors influencing power follow. It is believed that data showing the effect of the variables which govern the tendency for power to follow and maintain an arc after lightning flashover are quite necessary if best use is to be made of the lightning strength data in the present paper.

The use of the data on impulse strength of wood and porcelain to provide maximum resistance to lightning flashover within the dimensional limits of practical construction when combined with information on expectancy of power follow when lightning flashover does occur, should greatly increase the practical value of the data given us in this paper. It is to be hoped that the authors will continue their work to cover the problem of power follow.

P. B. Stewart (Cincinnati Gas & Electric Company, Cincinnati, Ohio): We have reviewed this article with a great deal of interest. We note in particular the reference to the reduced insulating properties due to moisture retained in wood poles.

Several years ago we made a study of the electrical resistance of wood poles. This work was covered in an article prepared for the American Wood Preservers' Association and can be found in their proceedings for the year 1936. In this study we found that the conductivity of wood varied with the moisture content. In most cases creosoted pine poles had lower resistance than cedar poles. This, however, was due to lack of proper seasoning.

It may be that there is a definite relation between the electrical resistance of wood and the impulse insulation strength of wood. This relation might hold true either above or below the fiber saturation point of the wood. In our study we found that a variation of moisture content above the fiber saturation point of wood had little effect on the electrical resistance. After the material had been seasoned below the fiber saturation point, a small variation in the moisture content had considerable effect on the electrical resistance.

Wood is a product of nature and has many variations. For this reason it is very difficult to determine accurate values from laboratory studies unless a very large number of tests are made. It is also very difficult to assimilate natural rain conditions due to the slow absorbing qualities of wood.

This article will be of great value in the design of wood-pole transmission lines.

L. G. Smith (Consolidated Gas Electric Light and Power Company of Baltimore, Md.): A paper of this nature is quite valuable to those designing transmission and distribution lines, since wood is of considerable benefit as insulation in raising the impulse flashover values. The formulation of these data so that they may be used as design information is of particular importance. It is frequently desirable to calculate the impulse level of new designs of lines in advance of their installation as otherwise wood insulation may be used wastefully and balanced designs not obtained. Moreover it is undesirable to have to test each design contemplated. The data given by the authors make design calculations of impulse levels possible. The ideal design is one in which a balanced design is obtained, that is, one in which the impulse flashovers from phase to phase and phase to ground on all phases are approximately equal.

Several years ago tests were made by the Locke Insulator Corporation for the Consolidated Gas Electric Light and Power Company to check certain designs of 13.2-kv, 35-, and 115-kv lines. As a result of these tests balanced designs of lines were obtained. These

Table I. Summary of Impulse Tests on 13.2-Kv Wood-Pole Lines

Double-Circuit Upright Construction With Four-Kv Arm Four Feet Below Lower 13.2-Kv Arm Ground Assumed to Be on Four-Kv Neutral and Secondary Neutrals and on Guy Wire

Flashovers in Kilovolts With 1½ x 40 Microsecond Positive Wave

Voltage Impressed	Guys With Two Porcelain Insulators—Steel Crossarm Braces								Guys With Two Porcelain Insulators—Wood Crossarm Braces						Guys With Wood Insulators Wood Braces			No Guys	
	No Guys		Thirty-Degree Guy at Bottom Lower Brace Within Two In. of Four-Kv Neutral	Horizontal Guy					Thirty-Degree Guy at Bottom Lower Brace Within Two In. of Four-Kv Neutral	Horizontal Guy					Horizontal Guy			Exp. Pro Gaps Multiplex Conn. Steel Braces	Pole Grd. Wire Steel Braces
	Steel Crossarm Braces	Wood Crossarm Braces		One Foot Below Lower Brace	At Bottom of Lower Brace	One Foot Below Lower Arm	At Bottom of Lower Arm	At Bottom of Upper Brace		One Foot Below Lower Brace	At Bottom of Lower Brace	One Foot Below Lower Arm	At Bottom of Lower Arm	At Bottom of Upper Brace	One Foot Below Lower Arm	At Bottom of Lower Arm	At Bottom of Upper Brace		
Column No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
									900	685	600	*495	*395	335	*840		*840	108	555
																			610 (−)
A phase to ground	765	840	555	705	655	495	395	345											
B phase to ground	920	1,230	675	895	*675	795	700	530	1,020	1,190	985	875	725	505	*1,230	*1,230	*1,230	83	410
		1,020 (−)					750 (−)								*1,020 (−)	*1,020 (−)	*1,020 (−)	91.5	
C phase to ground	530	710	345	465	*345	445	360	345	600	720	590	485	*360	335	*710	*710	*710	94	345
	445 (−)	690 (−)										530 (−)			*690 (−)	*690 (−)	*690 (−)		
A phase to *C* phase	705	*705		*705					*705	*705	*705				490	420	415	89.5	*705
B phase to *A* phase	700	*700		*700		*700	*700		*700	*700	*700	*700	*700		*700	*700	*585	78.5	*700
B phase to *C* phase	655	*700	*655	*655	*655	*655	*655		*700	*700	*700	*700	*700		*700	*700	585	81	*655
C phase to *C* phase	335	*705							*705						*705			88.5	*335

(−) Negative impulse wave value. * Measurements were not made—values assumed to be unchanged from other conditions. Where no values are shown flashover will go to ground instead of between phases at minimum voltage. Horizontal guys brought out from center line of pole on same side as the phase wires under test.

designs are covered in a discussion on page 199, AIEE TRANSACTIONS, 1936. These tests were made on assembled structures. These test results were compared with the data contained in the authors' paper and were found to check very closely.

The results obtained for the types of construction used on 13.2 to 35 kv are shown in table I, for the type of construction illustrated in figure 1. Figure 1 also includes an alternate design for a single-circuit line, using the top crossarm only with a third insulator installed near the pole, which is shown dotted. The results of this type of single circuit construction are shown in table II. An alternative design is shown in figure 2, the results of test on this type of construction being shown in table III.

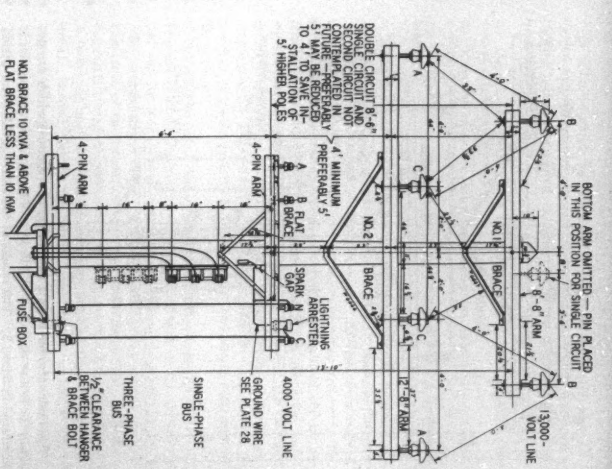

BOTTOM ARM OMITTED—PIN PLACED IN THIS POSITION FOR SINGLE CIRCUIT
DOUBLE CIRCUIT 8'-6" SINGLE CIRCUIT AND DOUBLE CIRCUIT NOT CONTEMPLATED IN FUTURE—PREFERABLY 5' MAY BE REDUCED TO STANDARD OF 5' HIGHER POLES
4' MINIMUM PREFERABLY 5'
4-PIN ARM
NO.2 BRACE
NO.1 BRACE
8'-6" ARM
12" ARM
13,000-VOLT LINE
4-PIN ARM
B FLAT BRACE
SPARK GAP
LIGHTNING ARRESTER
4000-VOLT LINE
GROUND WIRE SEE PLATE 28
NO.1 BRACE 10 RVA & ABOVE FLAT BRACE LESS THAN 10 KVA
FUSE BOX
THREE-PHASE BUS
SINGLE-PHASE BUS
½" CLEARANCE BETWEEN HANGER & BRACE BOLT

Figure 1

Table II. Summary of Impulse Tests on 13.2-Kv Single-Circuit Wood-Pole Construction

Ground Assumed to Be on Four-Kv Neutral on Four-Kv Arm, Seven and One-Half Feet Below

Voltage Impressed	Flashovers in Kilovolts With 1½ x 40 Microsecond Positive Wave					
	No Guys		Angle Guys With Two Porcelain Insulators, Wood Braces			
	Steel Crossarm Braces	Wood Crossarm Braces	One and One-Half Feet Below Bottom of Brace	Within Six In. of Four Kv	At Bottom of Brace	Within Six In. of Four Kv
B phase to ground	630	730	645	560	645	400
A phase to *B* phase	630	730				
B phase to *C* phase	570	575				

B phase is on the same side of pole as *C* phase.

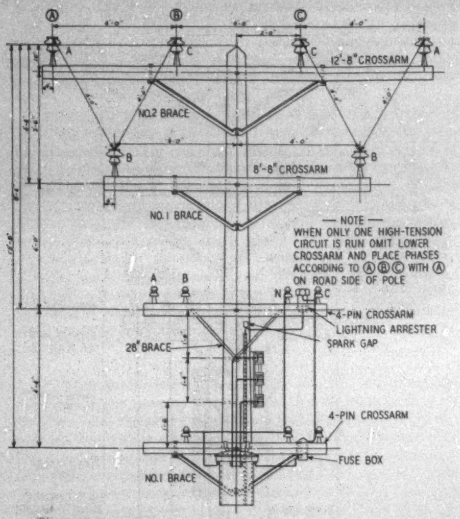


Figure 2 (left)

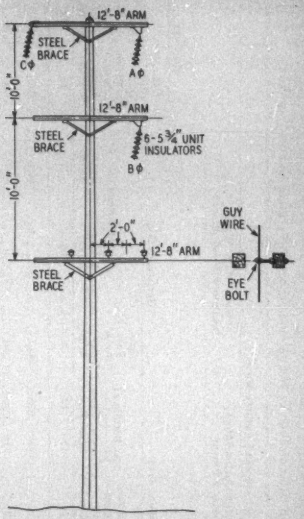


Figure 3 (right)

Tests were also made on a 66-kv type of structure, which was designed for future operation at 110 kv. This type of construction is illustrated in figure 3. The results of the tests on this construction are shown in table IV. Two types of arcing horns were used in these tests, the older type to which reference is made is the conventional type of horn, which had the effect of reducing the flashover of strings. In the new type of horn, the horn was straightened in order to effect the minimum reduction of flashover of the string.

In the tests on wood poles it is interesting to note the difference between the various types of poles. Our tests showed similar results in some cases, the moisture in the pole lowered the resistance sufficiently to permit the impulse generator to discharge through this resistance without obtaining an external flashover. One of the poles tested had an internal moisture content of from 112 per cent to 136 per cent. However, it is believed that if the generator had had sufficient current discharge capacity, external flashovers could have been obtained. Since pine poles immediately after creosote treatment may have a very high moisture content it is quite possible that the trouble noted by the authors may have been similar to that outlined above.

Another point of interest is the relatively small effect of the various sizes of insulators upon the flashover of the combination of pin-type insulators and wood crossarms, shown in figure 10 of the paper. It is believed that this is a very important consideration in the design of low-voltage lines. This feature may be utilized in the practical design of lines by choosing an insulator of sufficient size necessary to give the desired 60-cycle flashover and leakage characteristics. The remainder of the impulse level can then be obtained by the judicious use of wood, which usually will be at a lower cost than the cost for additional porcelain.

I. W. Gross (American Gas and Electric Service Corporation, New York, N. Y.): In the latter part of the paper the authors present impulse flashover data on typical transmission line structures carrying 33-kv and 66-kv circuits (figures 15 and 16). In figures 19*A* and *B* it is shown that the minimum impulse insulation of the line (which was phase to ground) was increased over 100 per cent for the 33-kv structure by the use of wood arm braces, wood bayonets supporting the ground wire, and an offset down lead.

While the gain in impulse strength is clearly apparent from the test results reported, it may be interesting to look at the operating record of this line before and after the above structural changes were made. The line which is 15 miles long is of standard two-circuit vertical configuration carrying a ground wire above the pole top. The ground wire is grounded every third pole, ground resistances ranging from 20 ohms to over 300 ohms. There are 483 structures in the line, 42 of them being guyed structures. The guys were insulated when the wood insulation was added.

During the four years prior to revamping, there was an average of 3.2 single-circuit outages per year due to lightning and 7.2 double-circuit outages per year. For the five-year period following revamping with wood insulation these were reduced to 2.2 and 0.6 on an average yearly basis. That is, the single-circuit outages were reduced 36 per cent and the double-circuit outages 92 per cent.

Where double-circuit lines are used to protect the continuity of service rather than for load requirements, the performance of the lines must be evaluated on the double-circuit outages alone, as a single-circuit interruption does not result in a service interruption. On this basis the improvement in performance of the above revamped 33-kv line is quite remarkable.

Table III. Summary of Impulse Tests on 13.2-Kv Double-Circuit Inverted Wood-Pole Construction

Ground Assumed to Be on Four-Kv Neutral on Four-Kv Arm Four Feet Below Lower Arm

	Flashovers in Kilovolts With 1½x40 Microsecond Positive Wave					
	Angle Guy With Two Porcelain Insulators—Wood Crossarm Braces					
Voltage Impressed	At Bottom of Lower Brace Within Six In. of Four-Kv *C* Phase, 50½ Degree Angle	At Bottom of Lower Arm in Six In. of Four-Kv *C* Phase 50 Degree Angle	At Bottom of Lower Arm With-in Six In. of Four-Kv *C* Phase 40 Degree Angle	At Bottom of Upper Brace, Within Six In. of Four-Kv *C* Phase 40 Degree Angle	One Foot Upper Arm in Six In. of Four-Kv *C* Phase 25 Degree Angle	Below With-in Six In. of Four-Kv *C* Phase 14 Degree Angle
B phase to ground	730	605	655	550		575
C phase to ground				550	585	575
C phase to *B* phase			655			

Corresponding records are not at present available for the revamped 66-kv lines, as in some cases the reconstruction work was not carried out on complete lines, and in other cases sections of intervening steel-tower lines obscured the records. An over-all survey of the performance records of these lines, however, seems to indicate a reduction in outages comparable to the impulse-insulation improvement shown for these 66-kv structures in figures 20*A* and *B* of the paper.

R. L. McCoy (Locke Insulator Corporation, Baltimore, Md.): The paper by Messrs. Sporn and Lusignan is of extremely great interest. The authors are to be congratulated for having carried on a well organized and comprehensive investigation on this important subject. Significant light has been shed on many obscure factors which in the past have been given little or no study. This paper gives stimulation to further thought along this line.

In transmission structures we are interested in the over-all impulse insulation afforded by various combinations of wood and porcelain insulation. The data presented bring out in a striking way the fact that to obtain the most benefit from wood as an adjunct to porcelain consideration must be given to the proper co-ordination of these materials. Analyzing the data presented in the paper, that is in figures 10*A*, 12*A*, and 13, it is seen that the positive-polarity impulse strength of wood taken as an adjunct to porcelain insulators varies from approximately 130 kv per foot with pin-type insulators down to approximately 55 kv per foot with ten-unit strings of suspension insulators.

A variation of a somewhat similar nature is noticed in the negative-polarity impulse strength as an adjunct to porcelain in figures 10*B*, 12*B*, and 13. This suggests as the authors point out that particularly in the case of the longer strings of suspension units the stress distribution between the porcelain and wood elements is badly out of proportion to their respective impulse strengths. The authors suggest that this may be due to unfavorable relative electrostatic capacitances of the various elements.

In order to check this proposal a four-foot section of creosote-dipped well-seasoned crossarm having a cross section of four inches by four inches was tested in series with the following dielectric members:

(*a*) One-unit heavy-duty switch and bus insulator having a capacity of 53 micromicrofarads at 60 cycles.

(*b*) A two-unit string of standard five and three-quarter-inch by ten-inch suspension insulators having a capacity of 15 micromicrofarads at 60 cycles.

(*c*) A 13 1/2-inch rod gap which should have relatively very low electrostatic capacity.

These dielectric members were selected because at standard humidity they have approximately equal full-wave impulse flashover values on a 1.5 x 40 positive impulse wave. All tests were made at an absolute humidity of 0.3 inch of mercury-vapor pressure. The four-foot wood section alone gave impulse strengths of 166 kv per foot positive and 154 kv per foot negative. The insulation added by this wood section to the switch and bus insulator, the two unit string of suspension units, and the 13 1/2-inch rod gap were respectively positive polarity 153 kv per foot, 158 kv per foot, and 172 kv per foot, negative polarity 155 kv per foot, 148 kv per foot, and 167 kv per foot.

It should be noted that in these measurements practically the full impulse value of the wood itself was added while in the case of the rod gap the wood added more strength than it possessed by itself. This suggests three things, first, that perhaps the relative leakage resistance of the insulation elements is also important, or perhaps the relative surge impedances of the elements which would take into account not only the relative capacities but also the relative resistances. Second, that as the authors' data might be interpreted to suggest the impulse strength of the wood section should be large in comparison with the impulse strength of the insulator element. Third, that the distribution of stress between the porcelain and wood elements may be a function of their relative time lags.

It is a matter of observation that the time lag at the full wave flashover on pin-type insulators and short strings of suspension units,

Table IV. Summary of Impulse Tests on 66-Kv Wood-Pole Lines

Pumphrey to Annapolis Future 110-Kv Line Construction

Six Insulators per String—Pole Ground Wire

	Flashovers in Kilovolts With 1 1/2 x 40 Microsecond Positive Wave															
	Guy Attached Six Feet Below Lower Arm										Guy Attached Four Feet Below Lower Arm at Various Angles to Pole					
	Old Type Arcing Horns				New Type Arcing Horns						New Type Arcing Horns					
	Straight Line Fittings	Angle Fittings			Straight Line Fittings			Angle Fittings			Straight Line Fittings, Insulators Vertical				Six-Unit String Only, Straight Line Fittings	
	Insulators Vertical	Insulators Vertical	30 Deg. Swing	45 Deg. Swing	Insulators Vertical	10 Deg. Swing	20 Deg. Swing	Insulators Vertical	10 Deg. Swing	20 Deg. Swing	17 1/2 Deg. 65 In. Clearance	42 1/2 Deg. 53 3/4 In. Clearance	51 Deg. 45 In. Clearance	60 1/2 Deg. 36 In. Clearance	Old Type Arcing Horns	New Type Arcing Horns
Voltage Impressed Column No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A phase to ground	*750	725	680	540	*1,025	*940	*835	*995	*895	*770					*520	*580
B phase to ground	*750	755	680	560	1,025	940	835	995	895	770	1,010	810	685	560	*520	580
C phase to ground	750	725	800		*1,025										520	*580

Eight Insulators per String—Pole Ground Wire

	115-Kv Expulsion Protective Gaps, No Arcing Horns	115-Kv Expulsion Protective Gap in Ground Wire, Wood Guy Insulators Above and Below 13-Kv Arm	Guy With Wood Insulators Six Feet Below Lower Arm. Old Type Arcing Horns				New Type Arcing Horns					
			Straight Line Fittings	Angle Fittings			Straight Line Fittings			Angle Fittings		
			Insulators Vertical	Insulators Vertical	30 Deg. Swing	45 Deg. Swing	Insulators Vertical	10 Deg. Swing	20 Deg. Swing	Insulators Vertical	10 Deg. Swing	20 Deg. Swing
Column No.	17	18	19	20	21	22	23	24	25	26	27	28
A phase to ground	470	490 (−)	905	*885	840		*490	*1,025	*930	*790	*995	*880	*720
B phase to ground	470	490 (−)	*905	*885	*840	585	490	*1,025	930	790	*995	880	720
C phase to ground	470	490 (−)	945	1,030 (−)	885			*1,025					

* Measurements were not made—values assumed to be unchanged from other conditions. (−) Negative impulse wave values. 13.2 kv on pole grounded in tests with old type arcing horns. No 13.2 kv on pole in tests with new type arcing horns.

say from one to five units, varies from four to eight microseconds, while on long strings of suspension units, ten units or more, it may run from 15 to 25 microseconds.

J. H. Hagenguth (General Electric Company, Pittsfield, Mass.): The authors have given the results of a very thorough investigation of the impulse characteristics of wood alone and wood in series with insulators.

Some tests on wood crossarms made in the high-voltage engineering laboratory in Pittsfield check the results obtained by the authors very closely. For instance, data published in a paper on "Impulse Voltage Strength of Insulators and Materials" by J. C. Dowell and C. M. Foust, figure 30 checks figure 4 of the paper for the flashover of pine at two microseconds almost exactly, while the Pittsfield values for the full-wave flashover are approximately eight per cent higher. Curves of figure 30 of the above reference begin to bend over considerably at about five feet—the flashover voltage of nine feet is only 36 per cent higher than at four and one-half feet—while the authors' figure 7, curve *A* indicates proportionality between flashover voltage and length of wood gap. In my opinion, it seems more reasonable to expect a smaller increase in flashover voltage for great length of wood, because the flashover of wood probably is a creepage phenomenon, which tends to be progressive, once an arc has started and the addition of a few feet of creepage path will not materially increase the flashover voltage.

Some investigation carried out on large-scale pole structures in the laboratory seem to check this contention. During these tests, wood crossarms with a length of as much as 11 feet and insulator strings of 9 to 15 units were in series. The ratio of measured to calculated (similar to table I of paper) flashover voltage was approximately 0.50, if the kilovolt values curve *A* of figure 7 of the paper are used, and 0.80 if the kilovolt values of the Dowell-Foust paper figure 30 for ten microseconds are used. The impulse insulation added per foot of crossarm during these tests varied between 30 and 50 kv per foot. The lower figure usually was associated with the longer wood gap. Lengths of wood poles up to 35 feet were arced over, when in series with an insulator string. During these tests it was also quite well established that the flashover voltage of an air gap 21 feet above ground was approximately the same as the same gap spacing with standard mounting. For instance, a 90.5-inch air gap 21.5 feet high, flashed over at 1,385 kv (1,400 kv standard rod gap) and a gap of 166 inches flashed over at 2,640 kv (2,530 kv standard rod gap). All these tests were made with 1.5x40 waves of positive polarity.

There appears to be some discrepancy between the results of figures 4, 5, and 7 of the paper. In figure 4, the flashover voltage of a pine crossarm of approximately 20 square inches is given as 530 kv at four feet, while figure 7 shows a flashover voltage of 610 kv for the same length. While this difference may be accounted for by the difference in treatment and general condition of the wood, these results do not seem to check figure 5*A*. The poles used for the test presumably had a larger cross section than the crossarm and should, therefore, be expected to have a relatively lower flashover voltage.

The authors mention very briefly the effect of rain on the insulation strength of wood, stating that a reduction of some 50 per cent might be obtained. Since the lightning disturbances usually occur under rain condition, it naturally would be of real importance to have more data taken under such conditions. It may, therefore, be of interest to compare dry flashover voltages as given in the paper with flashover voltages obtained under rain conditions in Pittsfield with a precipitation of 0.2 inch. The Pittsfield tests were made using a 66-kv pin-type insulator in series with wood crossarms.

Figure 4 (this discussion) shows a comparison between flashover voltages under the two conditions. It is a coincidence that the flashover voltages of the two insulators is the same, although one was tested, when dry, the other under rain. The considerable reduction due to rain in the insulation strength added by the wood is apparent especially for the first 12 inches. This is shown more clearly in figure 5 (this discussion) where the impulse insulation added to the pin insulator by an untreated pine crossarm is plotted, similar to figure 10*C* of the paper. Curve *C* on the figure 5 (this discussion) shows the ratio of wet to dry flashover, which is very low for short lengths of wood increasing to 50 or 60 per cent at about four feet, the maximum length investigated. This ratio is approximately the same for positive and negative polarity. For short lengths of wood, the calculations should, therefore, be based on the

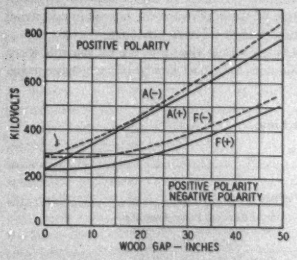


Figure 4. Impulse flashover characteristics of pin insulators plus crossarms—full-wave flashover

A—Creosoted fir crossarm, dry, same as curve *A*, figure 10*A* of the paper

F—New pine crossarm in series with 66-kv pin-type insulator rain test 0.2 inch per minute

Solid line—positive polarity

Dashed line—negative polarity

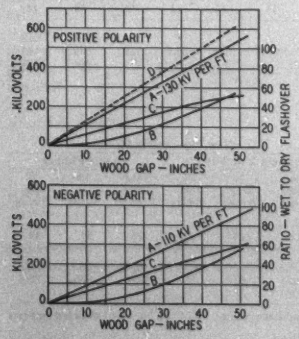


Figure 5 (left). Impulse insulation added to pin insulator by untreated pine crossarm—full-wave flashover

A—Curves for average insulation increase of 130 kv per fout and 110 kv per foot from figure 10*C* paper

B—Values obtained from wet flashover tests 66-kv pin-type insulator in series with pine crossarm, precipitation 0.2 inch per minute

C—Shows ratio of wet to dry flashover voltages

D—Pine crossarm alone

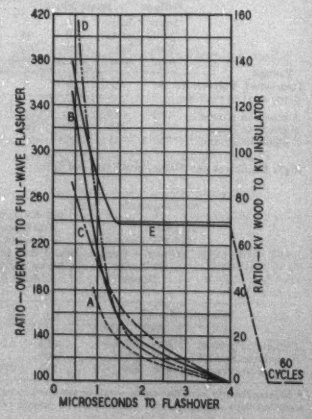


Figure 6 (right). Impulse flashover characteristics of pin insulators plus 36-inch wood crossarm. Positive polarity

A—Fir crossarm, dry, same as figure 11*A* of the paper

B—New pine crossarm, rain test 0.2 inch per minute plus 66-kv insulator

C—66-kv pin-type insulator alone

D—Overvoltage of crossarm alone (when in series with insulator)

E—Increase in strength of wood at short times to flashover. Ratio of kilovolts across wood to kilovolts across insulator

wet flashover of the insulator only, for greater wood gaps the strength added by the wood probably will not greatly exceed a value of 50 per cent of those given in the paper. During these tests the overvoltages required to flashover at short times were measured for the insulator alone and for the insulator in series with wood and are shown on figure 6 for a 66-kv pin-type insulator with 36 inches of crossarm. Curve *D* of this figure represents the added strength of the wood in terms of overvoltage obtained by subtracting curve *C* from curve *B* and using the value obtained for the full-wave flashover as 100 per cent. Of considerable interest is curve *E* which shows the ratio between the flashover voltage of the insulator alone to the flashover voltage added by the wood at different times to flashover.

This ratio is almost constant down to 1.5 microseconds and then the insulation strength added by the wood becomes greater than that of the insulator. The other end of this curve indicates zero strength added for 60 cycles. Although the 60-cycle tests were made after the crossarm was subjected to a considerable number of impulses and was badly splintered, it might be expected that the 60-cycle flashover under rain of the added length of wood would be considerably decreased, since the pin of the insulator at this low frequency is practically at ground potential, when the wood is wet and flashover of the combination will occur at the flashover voltage of the insulator.

R. H. Earle (Line Material Company, South Milwaukee, Wis.): This paper is an interesting addition to our knowledge of the electrical properties of wood when used as an insulator on power lines.

This investigation, particularly when compared with former ones, shows rather a wide divergence of numerical test data. Such a range of test results is not at all surprising, however, in view of the other electrical properties of wood.

It is generally recognized that the resistance of wood shows enormous variations and depends not so much upon the species of the wood as upon the amount of moisture that it contains. This is not necessarily free visible moisture, but is rather the moisture which is absorbed by the cells of the wood from the atmosphere and the moisture content of the wood depends upon the humidity of the air to which the wood is exposed. Penetration of this moisture through the wood is rather slow. In ordinary outdoor weather conditions, such as wood structures encounter, the humidity is, of course, constantly changing with the result that the wood is practically always either absorbing or giving off moisture and since the moisture is transferred through the wood slowly, the actual moisture content represents a summary of the weather conditions for perhaps several months past.

It is accordingly seldom that the moisture content of a crossarm or pole will be uniformly distributed and since the electrical resistance of the wood depends so markedly on the amount of moisture that it contains, the pole or crossarm is electrically a bundle of resistors in series and parallel combinations and each resistor has a different value. The over-all resistance of the wood with nonuniform distribution of moisture is apt to be lower than would be the case if the moisture content were uniform throughout the volume of the specimen. Furthermore, in specimens of large cross sections there is likely to be a greater variation in electrical resistance across the section than is the case in pieces of smaller sections.

Applying these facts to some of the conclusions shown by the author's paper, we find a plausible explanation for several of the conclusions. For example, conclusion number 3 states that lower flashovers accompany larger wood sections. This would be expected since in general the resistance of the large sections is less uniform and lower than for the small sections.

In conclusion number 4, it is likely that fir and pine would show the same flashover if they had the same moisture content.

In conclusion number 5, it seems likely that the newly creosoted pine poles had not dried out to the extent that the old ones had, and conclusion number 5 also bears out the belief that impregnation only permits the pole to shed water a little more readily and aside from this does not influence the moisture content.

In conclusion number 6, it appears likely that the effect of the rain was twofold: first, to reduce the resistance of the wood by penetration of the fibers, and second, to form an electrolytic conducting path over the surface of the wood due to the rain dissolving impurities on the surface of the wood and thereby forming an electrolyte.

It appears that the extreme ranges of insulating values of wood crossarms, poles, and strain rods would be obtained by assuming the dry flashover of a corresponding length of air as the upper limit and by running further investigations on water-soaked timbers of some wood that soaks up moisture readily, such as beech, birch, or maple. Due to the comparative ease of impregnating these three woods with water, the results of electrical tests on such specimens would probably be lower than would be obtained in practice where the species would be more likely one of the firs, pines, or cedars.

Philip Sporn and **J. T. Lusignan, Jr.**: Mr. Andrews comments on the ability of wood to help prevent 60-cycle power current from following. This is an aspect of the wood insulation study which is well worth developing, but one which was not included in our program. There were so many factors affecting the impulse breakdown of wood, it was impossible for us to add tests involving 60-cycle follow current.

Mr. Stewart mentions some moisture studies he has made on wood poles and the variation in insulation value observed. We imagine that his work involves the 60-cycle phase of the problem, possibly with respect to pole burning or leakage. The manner in which he found moisture to affect insulation is interesting, but we feel that the behavior under impulse might be different from that encountered under power frequency. Our principal reason for this thought follows from the ability of moisture to serve as a conductor under the two conditions of 60-cycle and impulse surges. In other words, the moisture conduction must be electrolytic and involves movements of relatively slow electrolytic ions which would not respond to impulse voltages, lasting only a few microseconds, but which would serve as fair conductors of current for the longer power-frequency waves. We concur with Mr. Stewart in that a large number of tests are necessary in order to obtain dependable results on wood, chiefly due to the variable nature of that material.

The manner in which Mr. Smith has applied the results of laboratory studies to his line designs is most interesting. It is gratifying also that his results and conclusions concur so well with the authors'.

The tests which Mr. McCoy describes add very interesting information regarding the ability of wood to increase the insulation strength of a transmission structure. All of the reasons why wood does not add its full strength to the porcelain members are not clear to us as yet. We offered the suggestion that capacity distribution was an important factor, since under impulse, the conducting properties of moisture had little time to enter. However, we feel that the effect of the relative time lags of the porcelain and wood which Mr. McCoy mentions to be appreciable also. In fact it was a little easier at the time to explain the shape of some of our oscillograms by considering the possible time-lag curves of the porcelain and wood as well as what we consider to be the relative voltage distributions. The time-lag phenomenon which Mr. McCoy mentions wherein pin-type insulators and short suspension strings have shorter time lags than long strings is something which seems to hold with most long and short air breakdown paths over insulation. In other words, short rod-gap spacings and small switch insulators also have much flatter voltage-time curves than the longer gaps and insulators. We feel that this is probably due to electrode surfaces being relatively larger compared to the shorter air paths, thereby introducing most uniform electrostatic fields and approaching the flat time-lag characteristics of sphere gaps.

The information which Mr. Gross gives us regarding the greatly improved performance of his 33-kv line is very gratifying as it proves the value of laboratory tests in predicting the advantages, or disadvantages, of certain contemplated structure changes.

Mr. Earle goes into an analysis of the moisture factor in wood and its effect upon the electrical breakdown. We concur with his thoughts, although we want to emphasize that the distribution of the moisture has probably as much or more to do with the breakdown voltage as the total amount of moisture itself. In other words,

we feel that the location of moisture areas both across the grain and along the axis are an appreciable factor in concentrating stress at certain points and thereby reducing the ultimate strength of the member as a unit. It is probably this factor that would make certain woods behave differently from others, even though they all have the same total moisture content.

Mr. Hagenguth supplements our paper with some very interesting thoughts and laboratory data. He compares the results of the Dowell-Foust paper with our results and in some cases notes agreement. He questions the straight-line curves of our figure 7 which conflict with their figure 30 and suggests that wood flashover is a creepage phenomenon. Although only a few individual pole specimens were tested, an appreciable number of wood lengths were flashed over from one to ten feet so that we believe that our data of figure 7 are fairly reliable, in so far as the specimens tested are concerned. We feel that these specimens were rather dry and typical of those poles to be encountered in service so that the values from the curves could be used rather freely for estimating purposes. We question the existence of much creepage phenomenon, particularly in impulse flashover where, at the short times involved, there is little chance for much creepage. We note a statement at the bottom of the above figure 30 stating: "Whether the wood is dry or wet, soaked in salt water or creosoted, makes little difference." With this our results disagree considerably. The lower ratio Mr. Hagenguth obtains with our values obviously results because of the higher flashover values we measured for wood alone. His results showing no change in air gap above ground checks similar tests made by us after the paper was written.

The disagreement Mr. Hagenguth finds between the crossarm data of figures 4 and 5 and the pole data of figure 7 is something which we noted during the tests. In other words, the cross-section phenomenon of figure 5 applies only to crossarms. Equivalent section areas of poles gave higher breakdown values, particularly with fairly dry poles. We felt that this was due to the unbroken grain structures of the complete poles wherein the discharges were kept along the outside surfaces, whereas the crossarms were cut from inner whole sections and add no continuous outer shells.

The additional wet tests made by Mr. Hagenguth to supplement the few which we made are most worthwhile. The "coincidence" he mentions in regard to the equality of the wet and dry flashover of the insulator alone, we feel to be a reality. On wet impulse flashovers of porcelain insulators we have usually found the voltage values to be about the same as the dry values.

A New Correlation of Sphere-Gap Data

Discussion and author's closure of a paper by D. W. Ver Planck published on pages 45–9 of this volume (January section) and presented for oral discussion at the instruments and measurements session of the winter convention, New York, N. Y., January 26, 1938.

P. H. McAuley (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): A simple and logical correlation of sphere gap sparkover data has been presented. It is particularly interesting to note that it brings out some of the discrepancies which we felt existed in the new AIEE values. The latter are averaged from tests made in different laboratories. Our values for the 50-centimeter sphere gap, for instance, are higher than the AIEE averages for the higher values of S/D. Table I, which includes some unpublished data, shows this condition. Similarly, our experimental curves show a value of 83 kv for positive-wave sparkover of the 6.25 centimeter gap at 3.125 centimeters spacing.

The practice of averaging test data by empirical methods is well justified in the case of the sphere gap. The original data were obtained in several different laboratories. The gaps were made of different metals and no doubt had different surface conditions. Mounting arrangements varied considerably. Clearances were different even for separate tests on the same gap in one laboratory. Considerably more data were available on the 25- and 50-centimeter sphere gaps than on the other sizes. For these reasons, our data were correlated according to average gradient curves for given ratios of S/D. The present author has extended this process with gratifying results.

Table I. Average Sparkover Voltages for 50 Centimeter Spheres; Westinghouse Data Compared to AIEE Values

	Westinghouse		AIEE	
S/D	Positive	Negative	Positive	Negative
0.5	550	520	547	519
0.6	609	575	605	573
0.7	662	623	655	615
0.8	702	662	698	651
0.9	732	694	732	681
1.0	758	721	758	707

S = spacing; D = diameter.

F. J. Vogel (Westinghouse Electric and Manufacturing Company, Sharon, Pa.): The engineer responsible for the design of high-voltage apparatus has long used logarithmic paper for plotting experimental data and design information. This has been true for many years and may be found amongst the writings of engineers associated with several companies. A reference to this fact is given in the paper "Factors Influencing The Insulation Coordination Of Transformers, Part II" by P. L. Bellaschi and F. J. Vogel, ELECTRICAL ENGINEERING, volume 53, June 1934, pages 870–6. This fact does not detract from Mr. Ver Planck's excellent paper since design engineers have not seen fit to call attention to the relationships existing between parts of similar shape.

In figure 1 of Mr. Ver Planck's paper, sphere-gap data are presented using ratios of spacing to sphere diameter as parameters. These data are plotted in figure 1 of this discussion, using given spacings as parameters. For a given spacing, it is seen that, as the sphere diameter is increased, the breakdown voltage becomes constant and presumably approaches that for plain surfaces. Values given in figure 1 of this discussion, for ratios of spacing of sphere diameter of 0.1, by changing the scale as shown, become breakdown values for plain surfaces. For comparison, points taken from Mr. Schumann's book on page 27 are shown. Schumann's values appear to vary as the 0.92 power of the spacing even down to very short distances. The use of the 0.88 power in figure 3 of Mr. Ver Planck's paper does not seem to be justified and perhaps points out an error in the sphere gap data for these distances.

Figure 2 of this discussion shows data established for design pur-

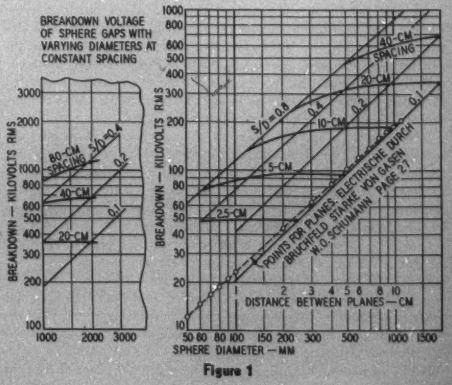


Figure 1

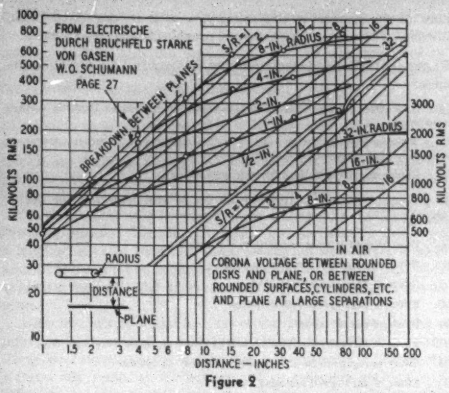


Figure 2

poses some years ago for the dielectric strength of rods and large-diameter parts. These data were obtained using sphere gap calibrations as standards of measurement but using spheres large enough to keep the ratio of spacing to sphere diameter one-half or less. The present calibration is not greatly different from the old one for these ratios, and the data are still sufficiently accurate for design purposes. It is to be noted that these data are plotted in the same manner as that used by Mr. Ver Planck. It is also of interest that these curves result in lower voltages than would be obtained by using the formulae derived by Mr. F. W. Peek, Jr., in his book "Dielectric Phenomena in High Voltage Engineering."

The use of curves, similar to figures 1 and 2, for design purposes, is desirable since they avoid calculation, give the design engineer a picture of the general relationships which exist, and permit the engineer to obtain his results quickly. When these two curves are used to help the engineer in forming judgment as to the clearances required for a given arrangement of parts, it is felt that figure 1 uses a better choice of co-ordinates, since the band showing the data is wider.

P. L. Bellaschi (Westinghouse Electric and Manufacturing Company, Sharon, Pa.): Professor Ver Planck has presented an interesting paper on the sphere gap by plotting the new standard sphere-gap data on logarithmic graph paper and applying the principle of similarity for electrical discharges. It should be stated that the new standard sphere-gap calibrations have been well correlated in the first place, otherwise the good agreement in tables II and III would hardly have been expected.

In practice a number of factors affect the sparkover of the sphere gap and rules in its use are accordingly specified to minimize these effects within a permissible limit. In view of this, the agreement of the calculated values with the standard data is amply close to establish with assurance the various relationships indicated. Among these relationships the factor of relative air density and the probable corresponding corrections are worthy of attention.

Correlation of data naturally will bring to light major discrepancies. For example, in figure 3, the circled point near the 16-kv value, through which the dashed line is drawn, appears out of place. As a matter of fact, this is an extrapolated data point. In the final revision of the new sphere gap standards the few remaining extrapolated data points were subject to close scrutiny. As the result of tests in the various laboratories, the actual data value was established as being 17 kv, thus the dashed curve in figure 3 lines up quite well with the Schumann values.

The correlation of data in high-voltage technique and engineering is not only desirable but even essential. The author makes the statement that the similarity principle for electrical discharges seems not to have been fully appreciated by engineers in this country. This statement appears hardly warranted, for as a matter of fact, the relationship indicated in the paper for the sphere gaps as well as similar relationships for toroidal and cylindrical electrode arrangements have long been known to obey the principle of similarity for electrical design. These relationships have been put to useful application for a number of years by electrical engineers in the design of high-voltage apparatus.

D. W. Ver Planck: As pointed out by Mr. Bellaschi the consistently close agreement shown in tables II and III would have been unlikely if the data had not already been well correlated. In fact this independent check of the regularity of the data is evidence of the excellent work done by the subcommittee who prepared the new sphere gap calibrations.

Two of the three data which were found to be conspicuously out of line have since been revised in a subcommittee report dated December 1937, and they now conform to the new correlation. As a result, the circled point in the lower left-hand corner of figure 3 moves up to the solid line, and the last item in the 50 column of table III becomes 758 instead of 738. The single serious discrepancy remaining is the last item in the 6.25 column of table III, and if Mr. McAuley is right this value would become 83 instead of 81.8, which is within about 1.3 per cent of the calculated value.

Mr. McAuley's suggestion that the AIEE valves for 50-centimeter spheres may be a little too low is supported by the calculations for this size being consistently higher than the data. In fact if the data were revised in the direction indicated by Mr. McAuley, slight changes in the parameters K and α could be made which would result in an even closer agreement between calculations and data for all the other sphere sizes as well.

Mr. Vogel's figure 1 has for its theoretical basis the alternative functional form, equation 2, given in the paper, although generality has been lost by making the horizontal coordinate D instead of $D\delta$. The diagonal straight lines, which are for constant values of S/D, are described by the empirical formula

$$V = G\,(D\delta)^{\alpha}$$

where

$$G = K\left(\frac{S}{D}\right)^{\alpha}$$

and K and α have the same values given in the paper. These formulas and a table of numerical values for G were included in the paper as first submitted but for brevity were omitted before publication. While this form when plotted gives a greater separation of the lines for small values of S/D, it crowds them more when S/D is large.

Figure 2 indicates a relationship closely paralleling that in the paper and apparently known for several years but unfortunately withheld from publication until now. Here again, as in Mr. Vogel's figure 1 generality has been lost by not taking account of air density through the full use of the similarity principle. This figure would be enhanced in value if it were shown that the parameters of the straight lines for constant values of D/R conformed to an orderly relationship analogous to that given in figure 2 of the paper.

Mr. Vogel's figure 1 shows a considerable difference between Schumann's curve for a uniform field and the diagonal straight line for $S/D = 0.1$. Actually Schumann's data and the most recent revision of the AIEE data for $S/D < 0.2$ determine a single smooth curve. A reduction of Schumann's tabulated data to effective sine wave values gives points which lie from one to four per cent below those in the figure. If the discrepancy is not due entirely to an error in plotting it might be partly explained by a failure to take account of the fact that Schumann's data are for 20 degrees centigrade while those of the AIEE are for 25 degrees centigrade. Correction of Schumann's data to 25 degrees centigrade would shift the curve 1.7 per cent to the right since $\delta = 1.017$ for 20 degrees centigrade.

The use of the exponent 0.88 in equation 4 has been questioned. As stated in the paper the true curve for uniform field and small spacings is not linear when plotted to logarithmic scales, although the curvature is small. Figure 3 shows this curvature and that equa-

tion 4 gives a good fit for the range below $(S\delta) = 2.0$. For the range above $(S\delta) = 2.0$ and up to at least 20 the line determined by the parameters in table I for $S/D = 0.1$ is in close agreement with the data as can be seen in figure 3 and the first line of table II. The exponent 0.92 suggested by Mr. Vogel will be found to give good agreement in the intermediate range $0.8 < (S\delta) < 7.0$ if used with the coefficient 31.2.

Although it is much the best for the entire sphere-gap range above $(S\delta) = 2.0$, the power function type of formula, equation 3, is not as good for uniform field and small spacing as the formula

$$V = A(S\delta) + B(S\delta)^{1/2}$$

a type probably first used by Peek. The author has found that with $A = 24.4$ and $B = 6.8$ it agrees with Schumann's curve over the entire range $0.2 < (S\delta) < 9.0$ to within about 1.0 per cent.

A New A-C Network Analyzer

Discussion and authors' closure of a paper by H. P. Kuehni and R. G. Lorraine published on pages 67–73 of this volume (February section) and presented for oral discussion at the instruments and measurements session of the winter convention, New York, N. Y., January 26, 1938.

W. W. Parker (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): 1. The paper which has just been presented is very timely because of the growing appreciation of the economies and advantages which accrue from the use of such facilities. As distribution systems become more and more complex the solution of their growing problems naturally becomes more difficult. Also the time required for analytical solutions increases beyond all reason unless improved methods are available. So it is that the members of the Institute should find this subject of live interest.

2. Several a-c calculating boards have been built for various companies for their private use and the investment made by these companies has been adequately justified from the excellent results which they have obtained. Along this line the *Electrical World* article of November 23, 1935, by Mr. T. G. LeClair, will probably be of interest. (Several slides were shown showing the a-c network calculator in Chicago, one in New York, one at East Pittsburgh and a new one just installed in Chattanooga, Tenn. This new one is shown in figure 1 of this discussion and employs a 100-volt one-ampere power level which is most convenient to use. This is the very latest in a-c calculating-board design.)

3. It seems that the best contribution that can be made to this discussion and one which will be of interest to the majority will be a brief outline of experience with one of these calculators. In the past eight years approximately 200 studies have been made embracing most of the systems in this country, as well as some from India, Mexico, and Canada. These can be roughly classified as follows:

50 per cent—Voltage-regulation and load-control studies to determine:

(*a*). The effect of new lines or synchronous condensers to improve voltage conditions.

(*b*). Transformer application both as to size and type, i.e., whether quadrature or in phase tap-changing equipment is desired.

(*c*). Choice of system voltage for new installations.

30 per cent—Stability studies both static and transient for determining:

(*a*). Power limits of lines or portions of network.

(*b*). Effect of increased machine inertia.

(*c*). Effect of high-speed excitation.

(*d*). Effect of high-speed fault clearing.

(*e*). Effect of circuit layout.

(*f*). Effect of auxiliary equipment such as reactors, neutral resistors, etc.

(*g*). Effect of connections of "topping turbines" to system.

(*h*). Effect of high-speed reclosing.

In fact, it is very doubtful if the many applications of 30-cycle reclosures on 110-kv systems would have been made if it had not been for the possibility of adequately predetermining just what would happen with an alternating current network calculator.

15 per cent—Short-circuit studies for determining:

(*a*). Breaker application.

(*b*). Relay application.

5 per cent—Miscellaneous studies including secondary-distribution-network studies, theoretical and special design problems.

4. The above classification does not include the voltage-recovery studies which are covered in a paper presented at this convention by Messrs. Evans and Monteith, entitled "Recovery Voltage Characteristics of Typical Transmission Systems and Relation to Protector-Tube Application."

5. These studies have resulted in system economies by obtaining (1) the most effective use of existing facilities, (2) the deferring of capital expenditures, and (3) the determination of the type and location of new equipment.

6. Summarizing, the use of the a-c calculating board or network calculator is being more and more appreciated by planning engineers, system operators, utility managements and even, at least in one instance by a public utility commission.

R. C. R. Schulze (Public Service Electric and Gas Company, Newark, N. J.): There are several points which have not been mentioned yet in the discussion. The principal one I have in mind is the ease of operation of this new G.E. analyzer. There are several features

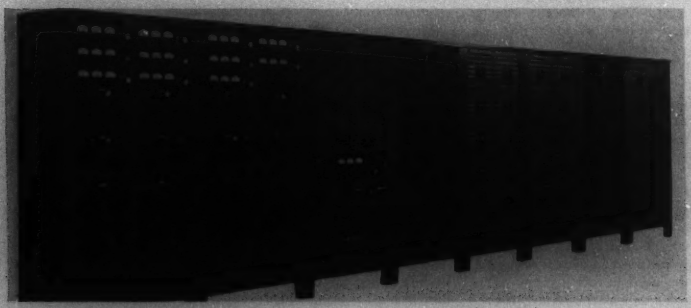


Figure 1

that make operation easier. One is the fact that loads can be set up as resistance and inductive reactance in parallel—so that watts and vars can be adjusted separately. Anyone who has tried to adjust a load with resistance and reactance in series will appreciate the convenience of the parallel connection.

Another factor is the arrangement of jacks and plugs. By making all connections in one (or two) places, the time involved in setting up a network is reduced, it is easier to see just what has been set up, and there is less chance of an error in the connections. We have had ten years of very satisfactory experience on our d-c table with this method of making connections.

The metering scheme is quite flexible, and permits reading almost anything desired. The ability to read watts and vars directly saves a large amount of slide-rule work. This not only saves a large amount of time in the analysis of the data, but it also saves time when adjusting the loads and generator units when making an analyzer setup.

Aside from the technical features of the master meters, the use of light-beam instruments is a distinct help to the analyzer operator. There is a reduction in eye-strain, since it is unnecessary to lean over a meter and squint at the pointer and its reflection with one eye. With the light-beam instrument the reading is essentially the same from any angle, so both eyes can be used. Also, it is possible to read these meters from anywhere in the room, not to the last tenth of a division, of course—but with a fair degree of accuracy. This means that one man can both adjust a load impedance and read the meter from that position, so that it is possible for one man to set up and adjust a network. Of course a second and even a third man would be useful, but the point is that this analyzer can be operated conveniently by one man.

I might add that our experience agrees with that mentioned by several of the previous discussers, in that it is possible to obtain results on a calculating table in much less time and with better assurance of accuracy than can be done by slide rule. This has been demonstrated on several occasions.

Our experience with our d-c calculating table, and with the results obtained on several visits to an a-c calculating table, has been very satisfactory. This experience, plus the complexity of the problems in system layout and operation, has led our executives to purchase the first step of an a-c network analyzer of the type described here.

Mr. Kuehni mentioned the types of problems which are usually solved on the a-c analyzer. A telephone friend of mine inquired about the possibility of studying the inductive coupling between a telephone line and our power lines, and one of our engineers has already suggested the study of transients on our analyzer. It is evident that we are going to have a variety of problems offered for solution on the analyzer.

It is our belief that this analyzer will not only be of considerable help in solving our technical problems, but also the savings resulting from its use will soon pay its cost.

E. W. Kimbark (Polytechnic Institute of Brooklyn, Brooklyn, N. Y.): The network analyzer described in the paper is the third principal design which has appeared. The first one, located at Massachusetts Institute of Technology and built jointly by the Institute and the General Electric Company in 1929, operates on a frequency of 60 cycles per second with a base voltage of 200 and a base current of two amperes. The second design, of which several boards have been built by the Westinghouse Company, uses 440 cycles and a base of about 100 volts, one ampere. The new design uses 480 cycles, 50 volts, 0.05 ampere.

The decrease in base voltage and current of each successive design is closely related to advances in the instrument art. The MIT network analyzer originally used suspended-coil wattmeters and thermocouple ammeters and voltmeters, all of which were sluggish, particularly the thermal instruments. The Westinghouse analyzers introduced dynamometer ammeters and voltmeters, one coil of which was inserted in the network while the other was fed from an instrument phase shifter. By supplying the larger part of the instrument power from the phase shifter, faster instruments were obtained without increasing the burden on the network. In the new analyzer described in the paper a great reduction in instrument burden without sacrifice of speed or accuracy has been effected by the development of suitable amplifiers.

I have had the opportunity of operating both the MIT network analyzer and the new General Electric analyzer and can testify to the improved "usability" (as the authors term it) of the new design. The elimination of calibration tables and plugging diagrams, the centrally located switches eliminating the need for an operator to move the instrument plugs, the fast easily read light-beam instruments, the fact that all three instruments indicate simultaneously, the good voltage regulation of the generator units and their independent continuous phase and magnitude adjustments, all contribute to this usability. Messrs. Kuehni, Lorraine, Thompson, and Slinger are to be congratulated on their excellent design of this new network analyzer.

A frequency in the neighborhood of 500 cycles per second has been chosen by two different groups of network analyzer designers and therefore seems to be well established. This frequency permits the use of smaller reactors and capacitors than those required at 60 cycles with the same voltage and current base. The use of a much higher frequency would increase the difficulty of limiting undesired electromagnetic and electrostatic coupling between network elements to a negligible value.

For experimental work the use of 60 cycles and of the higher voltage and current base has proven very desirable at MIT, as it permits various transformers, rotating machines, and instruments which are not part of the regular equipment of the network analyzer to be pressed into service.

A fair number of studies made on network analyzers have been concerned with transformers for controlling power flow in a loop by means of phase shift, and, although the required results have always been obtained from the analyzers, there has been no really satisfactory and convenient means of representing on the analyzer the phase-shifting transformers of the power system.

A very interesting and ingenious form of network analyzer (described in British patent specification No. 476,164) has been invented by Charles L. Blackburn, and put into service for the firm of Merz and McLellan in London. In the Blackburn network calculator an impedance unit (representing resistance and reactance) consists of two three-winding transformers with ratios controlled by tap switches and serving to connect magnetically four electrically independent circuits, the voltages of which represent respectively in-phase voltage, quadrature voltage, in-phase current, and quadrature current of the represented network. Such an impedance unit is furnished with four six-pole sockets, and the various units are interconnected by six-conductor flexible cords and plugs. This seems very complicated compared with the conventional form of network analyzer. However, the Blackburn calculator affords a ready representation of the following, all of which are obtained with difficulty on the conventional analyzers: (1) negative resistance, (2) transformer of complex ratio one to a for representing simultaneous faults, etc., (3) transformer with phase-angle control.

A large portion of the studies made on network analyzers are concerned with transient stability. In these studies generator swing curves are obtained step-by-step. The network analyzers have facilitated what was formerly the most laborious part of the process, the determination of the outputs of the several synchronous machines for given angular positions of their rotors. The other parts of the process, especially the computation of the changes of angular position of the generators in a small time interval, although relatively simple, are now the "bottle neck" of the procedure, keeping as many as four to six men occupied in contrast to one man operating the network analyzer itself. I venture the prediction that in the future generator swing curves will be drawn automatically on an output table, one pencil for each generator. This will be accomplished by an interconnection of a network analyzer and a differential analyzer, two integrators of the latter being used to solve the equation of motion of each generator. The electrical output of each generator unit will control through a watt relay and servo-mechanism the displacement of the first integrator. The output of the second integrator will rotate the phase-angle dial of the generator unit and also actuate a pen-

cil. Such an arrangement would greatly speed up a stability study. One necessary feature of this arrangement, a generator unit having good voltage regulation, has already been developed by the authors of the paper.

H. L. Hazen (Massachusetts Institute of Technology, Cambridge): As a preliminary comment I wish to say that the paper by Messrs. Kuehni and Lorraine describes a fine piece of engineering equipment that has resulted from excellent engineering design. It should aid materially in developing the growing appreciation on the part of power-system engineers of the great power of an a-c network analyzer for the study of power-system operation. When these engineers have once experienced the facility with which they can study the operation of their system in miniature, they usually become enthusiastic about this method of study.

In this discussion I wish to review the development of such a-c network analyzers by stating in broad terms the nature of the essential design limitations in such devices, and to sketch briefly their development as determined by these limitations.

After the development of the technique of power-system representation by static apparatus (reference 6 of the paper) had been made, the design of a device which would be effectively applicable to actual commercial problems was found to be restricted by two primary limitations. The first and most important is that imposed by instrumentation. The second, less fundamental but a rather troublesome detail for the designer, is imposed by the difficulty of proportioning the units—particularly the inductive-reactance units—to properly represent their prototypes.

The effect of the instrument limitation is clearly shown by a consideration of the three principal designs of network analyzers to date; namely, the jointly designed and constructed MIT-General Electric Company analyzer erected at MIT, the Westinghouse design, and the General Electric design reported in the present paper.

In the analyzer at MIT the design with the metering originally provided was developed around the minimum burden for which a-c instruments of good accuracy could be built at the time of its development. These burdens were of the order of 1.5 to three milliamperes for potential elements, and roughly 0.1 volt for current elements. The criterion was adopted that an instrument potential element should not impose a burden, in comparison with a five per cent system load, of more than one or two per cent, and that an instrument current element similarly should not increase the impedance of a series element having a five per cent drop by more than about one per cent. This indicated current and voltage bases for the device of about two amperes and 200 volts, respectively. Assuming the analyzer to be in operation with ten generating stations each capable of 300 per cent of base output, the power requirement for the board is in excess of 12 kva, single phase, which evidently requires a sizable main supply generator in order to maintain reasonable voltage balance on the primary side of the phase-shifting transformers representing the generators. This indicated the use of 60 cycles because of the cost of substituting a higher-frequency generator for the 75-kva, 60-cycle, sine-wave generator already available in the laboratory. The limits of error set for this first design were one per cent for all units and somewhat lower limits for most of the instruments. These tolerances have been found, in the light of subsequent experience, to be unduly severe—a fact which has enabled the subsequent designs to be made somewhat more convenient in operation. The original metering equipment in this design was rather show—a condition that, as mentioned below, has been entirely corrected with recent modernization of the metering equipment of this original analyzer.

While this MIT-General Electric design was in progress the Westinghouse Company started on a somewhat different attack. They reduced the instrument burden by using dynamometer-type instruments and exciting one winding from an independent source that could furnish any desirable amount of power. This resulted in a sufficiently low burden for the other coil of the dynamometer instrument to permit its direct insertion in a network whose nominal current and voltage are somewhat less than those of the first-mentioned design. These instruments have a fast response. Two such instruments were used—one as a voltmeter with a low current requirement, and one as an ammeter with a low potential drop. This design uses a frequency of 440 cycles, which reduces the weight of the reactor units which are necessary to obtain appropriate reactance-to-resistance ratios, and also makes practicable reactor units with decade steps. This design of board has proved very useful. With the separately excited type of instrument the accuracy of readings is directly dependent upon the accuracy of setting of this excitation, both in magnitude and phase, and careful operation is therefore required to get good results. Nevertheless the effectiveness of this design is indicated by the fact that a number of such boards are in successful operation.

In the third design—that described in the paper under discussion—a quite different instrument technique has been used which has resulted in a very marked reduction in the current base. Specifically, the use of precision linear amplifiers in connection with semi-standard instrument elements has permitted the reduction of the voltage and current bases to the 50 volts and 50 milliamperes mentioned in the paper. This use of small base quantities, together with the use of 480 cycles, has resulted in relatively light, small units, decade steps for inductance units, and fast direct-reading instruments. This design also has the additional advantage of a low base current; namely, that the resistance of the long leads required for central plugging can be tolerated. Thus it appears that this third design has succeeded in realizing most of the features sought in an alternating-current network analyzer. This new analyzer is about as simple to set up and operate as is possible in such a device, remembering that the problems to be studied are inherently complicated in the sense of involving huge quantities of detailed numerical data.

It may be mentioned, however, that this new development—significant as it is—has not rendered earlier devices obsolete. The new metering techniques are just as applicable to a board such as the 60-cycle analyzer at MIT. In fact new, fast, direct-reading instruments have been incorporated into this analyzer which are described in a paper in preparation for publication. The new instruments, including a semi-standard portable wattmeter using a linear, degenerative feedback amplifier in the potential circuit, have been demonstrated to be sufficiently fast so that the speed at which readings can be made on this analyzer is determined not by the time which is required for the instruments to furnish indications, but by the rate at which the data can be reliably recorded. Thus the rate at which results are obtained is substantially the rate at which an engineer can record the readings obtained. This older analyzer requires somewhat more man power (estimated at one assistant operator) because the low-impedance base of this device requires interconnecting the units, and plugging for the current measurements, at the units themselves rather than at a central point. Another way in which this older analyzer has required somewhat more time is in the use of calibration charts for the reactance units—a method adopted at the time of the construction of this analyzer when smaller tolerances were prescribed than have proved necessary for the usual system studies. Now a much faster and simpler scheme of determining reactor unit settings is used in which an extreme mis-setting of a unit may amount to about three per cent as against about one per cent for the more accurate procedure. This considerably reduces the total time required for setting up a system on this analyzer. With the new metering equipment which has been in continuous service for some months, and the shorter set-up time involved by using the less precise calibration, the unit at MIT can deliver results very rapidly and, in the hands of good operators, remarkably reliable data are secured in very reasonable lengths of time not greatly in excess of that required on the newer devices.

In the experience obtained over a period of years in the use of this analyzer, both by students of electrical engineering and by the engineers of commercial companies, it has been found that skilled operators add greatly to its effectiveness. This is particularly true in the case of the use of the board by commercial-company engineers who, although thoroughly familiar with the characteristics and peculiarities of their systems, often do not visualize the way that the system conditions in which they are interested can be most easily represented in miniature, or how the information they wish to secure from the analyzer can be most readily obtained. It has been found that

the present complement of a skilled operator and an assistant, together with two company engineers—one to direct the study as a whole, and the other to record data—make a very effective crew. The directing engineer states what he wants, and the operator determines the manner of obtaining the desired results. With such a group it is found that work progresses easily and rapidly, and that the mistakes occasionally made are caught before an appreciable loss of time is involved.

Summarizing, I wish to say again that the new development described by Messrs. Kuehni and Lorraine represents the excellent result of first-class engineering design which marks a distinct step forward in the facilities available for studying power-system networks. At the same time, older equipment in which advantage has been taken of newer metering ideas is still very serviceable and competes with the newer equipment on fully equal terms as to accuracy, and on nearly equal terms as to time required.

L. A. Nettleton (Consolidated Edison Company of New York, Inc., New York, N. Y.): Mr. G. C. Crossman, of the Consolidated Edison Company, and I recently had the privilege of using the G.E. network analyzer in connection with some studies of the New York Consolidated Edison system. We found the network analyzer to be simple to set up and operate. The per cent basis for marking the line and load units and instrument scales proved to be convenient since our impedance values which had previously been established on a 100,000-kva base could be transferred directly to the analyzer units with no additional conversion, so that per cent watts and vars read directly as megawatts or megavolt-amperes.

In taking readings, the light beams swing across the instrument scales and become stationary almost instantaneously upon closing the circuit key. After turning the scale-selector switch to give the best scale reading, the voltage, current, and watts are read and the wattmeter switch thrown to read vars. One operator could read all four quantities on successive circuits as fast as they could be recorded. We expected some confusion to result from the large number of scale multipliers but in practice there was no trouble. The voltage multiplier was unity in practically every case and only the current multiplier, which applied also to watts and vars, was recorded with the readings.

The 100- or 150-scale division instruments can be read to about one-fifth of a scale division and the phase-angle dials can be set or read to about one-fifth of a degree. In comparing the readings of six or more circuits tied to a common point it was found that the total watts entering that point invariably checked to within one per cent of the total watts leaving the point.

The generator units proved to have very flat regulation, requiring only slight readjustment when loading conditions were altered. In short-circuit studies it was found convenient to throw the supply voltage switch to one-half or one-quarter normal voltage temporarily in order to check the short circuit current and insure that no circuits would be overloaded on normal voltage.

The instrument system worked perfectly during the two weeks of the study. There is no danger of overloading the ammeter since an off-scale deflection automatically short-circuits the ammeter shunt.

It is sometimes desirable to close two or more circuit keys at the same time to meter the combined circuits. However, it occasionally happens that two keys are inadvertently closed at the same time, joining together two circuits which may be at different potentials. Sometimes this causes a generator fuse to blow, resulting in a few minutes delay to locate and replace the blown fuse. As this condition may not be discovered immediately and as it is not always easy to determine visually whether or not a fuse is blown, it might be desirable to provide some means for indicating the presence of a blown fuse.

In our studies it was sometimes necessary to consider the effect of load-regulating transformers, controlling both voltage and phase angle on parallel feeders. The voltage control feature presents no difficulties since the analyzer is provided with auto transformers which can be connected in the circuit at the appropriate location and adjusted to the desired voltage ratio. However, where there is a difference in the desired phase angle on parallel feeders the problem is not so easy when the system is set up on a "one line" or single-phase basis. There are several methods of obtaining this difference in angle on one of the feeders, but all require considerable adjustment before a balance is obtained. In our case the required displacement was obtained by one generating unit in series with the circuit and the watts or vars supplied to or taken from the circuit by this unit were neutralized by another generating unit together with a series stabilizing reactance connected in shunt with the circuit. For each change in loading conditions these two generators were adjusted in voltage and phase angle until the desired displacement angle was obtained, and until the volts, watts, and vars read the same on each side of that point.

Since these methods require considerable juggling, it would be a great convenience in problems involving such load regulating equipment if devices were available that would introduce the desired phase angle in a circuit and maintain that phase angle difference regardless of voltage or loading.

G. C. Crossman (Consolidated Edison Company of New York, Inc., New York, N. Y.): The increasing size and flexibility of modern power systems has created problems which can no longer be solved quickly and easily by analytical or even d-c calculating-board methods but which require for such solution some sort of a-c calculating device, such as the network analyzer described by Mr. Lorraine and Mr. Kuehni. Continued system growth of many large power companies tends to increase the number of these problems to the point where it becomes desirable for these companies to own and operate such a calculating device themselves rather than rent existing ones. It would seem that the very small currents and high frequency employed in this network analyzer would present rather difficult maintenance problems to such a power company. While most of the testing and maintenance of the line, load, and generator units of the analyzer could probably be handled by the average test department, it would seem likely that the testing and adjustment of the amplifiers and master instruments would require rather special instruments and special training not ordinarily available in such test departments. It was not brought out in the paper whether the trimmer capacitors on the potential shunt are adjusted once and for all at the factory or whether they might require subsequent adjustment; such adjustments would seem to require rather sensitive and special instruments.

It would be interesting to know what instruments and general methods the authors have used or plan to use for the maintenance of their analyzer.

R. N. Slinger (General Electric Company, Schenectady, N. Y.): In their paper entitled "A New A-C Network Analyzer," Messrs. Kuehni and Lorraine have given an excellent description of this new device. As one of those who have had occasion to use the analyzer extensively since it was placed in operation, I have been impressed more and more as time goes on by the many ways in which the device can help engineers solve their problems and it would seem that a few remarks on this subject might be appropriate.

Any power company engineer who has been faced with the necessity of obtaining answers to any of the following problems, and particularly when on an emergency basis, will immediately recognize how helpful it would have been to him to have an analyzer available for his use. A list of some of these typical types of problems for which the network analyzer is especially adapted might include the following:

1. Effect of various amounts of synchronous condenser capacity on bus voltages at important stations under both normal and emergency operating conditions.
2. Determination of best location for new generation.
3. Determination of best arrangement of station or system connections for new generation in order to obtain the maximum degree of system stability and investigation of the effect on breaker interrupting duty.
4. Determination of the actual value of a proposed addition to a transmission or distribution system in terms of improved voltage conditions, increased stability limits, or reduction in the loading of existing circuits.
5. Determination of wattless flow around a system and selection of methods for reducing it to a minimum.

6. Determination of bank ratings in the case of a new transformer bank that is to be connected in a loop circuit or a network or the determination of the ratings of individual windings of a three winding unit for use in a loop circuit or network.

7. Determination of improvement in system voltage conditions to be expected from the addition of a voltage regulating transformer or a phase shifting transformer to a loop circuit or a network.

8. Determination of the time required for a synchronous generator to pull out of step after complete loss of excitation and the effect upon the rest of the system.

9. Investigation of the starting and pull-in characteristics of large synchronous motors connected to a transmission system at some distance from the nearest generating station.

10. Determination of relay currents under three-phase and unbalanced fault conditions, particularly on tie lines during transient disturbances.

All of these problems can be and are studied in part by tedious long-hand calculation methods, but the excessive amount of time and labor involved usually places a serious limitation upon the number of operating conditions that it is feasible to consider. When such problems are solved with the aid of an a-c network analyzer, it is possible to investigate many different operating conditions in a surprisingly short space of time. As a result, studies made in this manner can be and usually are much more comprehensive in nature, covering not only normal system connections and the variations that may be under consideration but also the emergency conditions which unfortunately seem to get overlooked in the average long-hand study until after these contingencies arise.

Perhaps it should also be pointed out that once a system network is set up on an analyzer, such as the one described by Messrs. Kuehni and Lorraine, it is possible to make several different types of studies on the system with practically no change required in the connections except to represent changes in the original conditions. Thus a power-flow study may be made on a system in order to determine circuit loadings, bus voltages, condenser capacity requirements, etc., followed by an investigation of breaker interrupting duties under short-circuit conditions. This may in turn be followed by an investigation of transient stability limits or breaker times required to maintain stability with certain specified power transfers. During the course of the stability study, tie-line currents may be read at troublesome relay locations with perhaps a more comprehensive short-circuit and relay study made immediately afterward. Thus the engineer responsible for system planning and design is able to obtain a much better appreciation than he could otherwise have, of the influence of existing and proposed stations and equipment upon system bus voltages, power flow, stability limits and breaker duty, and he can feel considerably more certain that he has not overlooked something of importance that should have been taken into account.

The analyzer which Messrs. Kuehni and Lorraine describe is particularly helpful in this respect since it enables the power system engineer using it to think in terms of system quantities with which he is already familiar, thereby enabling him to keep his thinking straight. This is made possible by calibrating the entire analyzer including the master instruments in per cent. Thus it is a simple matter to interpret the readings in terms of system quantities; for example, a reading of 65 per cent watts and 40 per cent vars would represent 65,000 kw and 40,000 reactive kva, respectively, on a 100,000-kva base or half those amounts on a 50,000-kva base.

This particular analyzer has been in operation only about six months but in that time it has been used for ten different studies by engineers representing 13 different power companies and industrial concerns. The studies have varied in length anywhere from one day to four consecutive weeks and have covered practically every one of the various types of problems previously listed. It is safe to say that these studies have not only solved specific problems but they have also done much toward giving a clearer picture of system performance to the respective groups than they have ever had before. Furthermore, the results of the studies in some instances were quite different than had been expected and occasionally brought to light new problems that had previously passed unnoticed.

H. P. Kuehni and R. G. Lorraine: The authors are highly pleased by the reception given this paper. The discussion has been of such constructive character as to add materially to its value. The growing importance of the analyzer as an engineering tool, particularly for utility engineers, has been stressed. It is gratifying to know that those who have used the analyzer described in the paper feel that it has the degree of accuracy and the speed, facility, and ease of operation that was expected.

Professor Hazen called attention to the importance of proper instrumentation in the design of an analyzer. It is interesting to learn that advances in measurement ideas were incorporated in the MIT network analyzer to greatly improve the speed of taking readings.

Mr. Parker has presented a comprehensive statistical analysis of the practical types of studies made with the analyzer. Of course, the individual studies are not, in general, quite as clean-cut as one might be led to believe from his per cent tabulation. In practice each study more nearly is a combination of several types, one usually leading to another as the occasion arises. Mr. Slinger described many of the ways in which the analyzer may be of help to the engineer.

Mr. Schulze has given an excellent discussion of the salient design features which contribute to the ease of operation of the new analyzer based upon his wide experience with network analyzers of different types.

There are undoubtedly network studies in which it would be desirable to have available special units to represent phase-shifting transformers as suggested by Messrs. Kimbark and Nettleton. However, these cases are quite rare at present. Because of the cost of such units, it was decided to use generator units for this purpose, even though they are admittedly somewhat more awkward to operate than phase shifting transformers might be. The integrators and servo-mechanisms used with generators for automatically recording swing curves, which Mr. Kimbark predicts will be integral parts of future analyzers, are at present in the same category with the phase-shifting transformers. These devices can be and may be incorporated in the analyzer when there is sufficient economic justification.

Mr. Crossman is of the opinion "that the testing and adjustment of amplifiers and master instruments would require rather special instruments and special training not ordinarily available in testing departments." It is the authors' belief that any one familiar with ordinary instrument calibration routine methods is perfectly qualified to check and adjust the instrument system by following a few instructions of very simple nature. With the exception of perhaps a small portable commercial cathode-ray oscillograph of a type which are so widely used today, no special instruments are required.

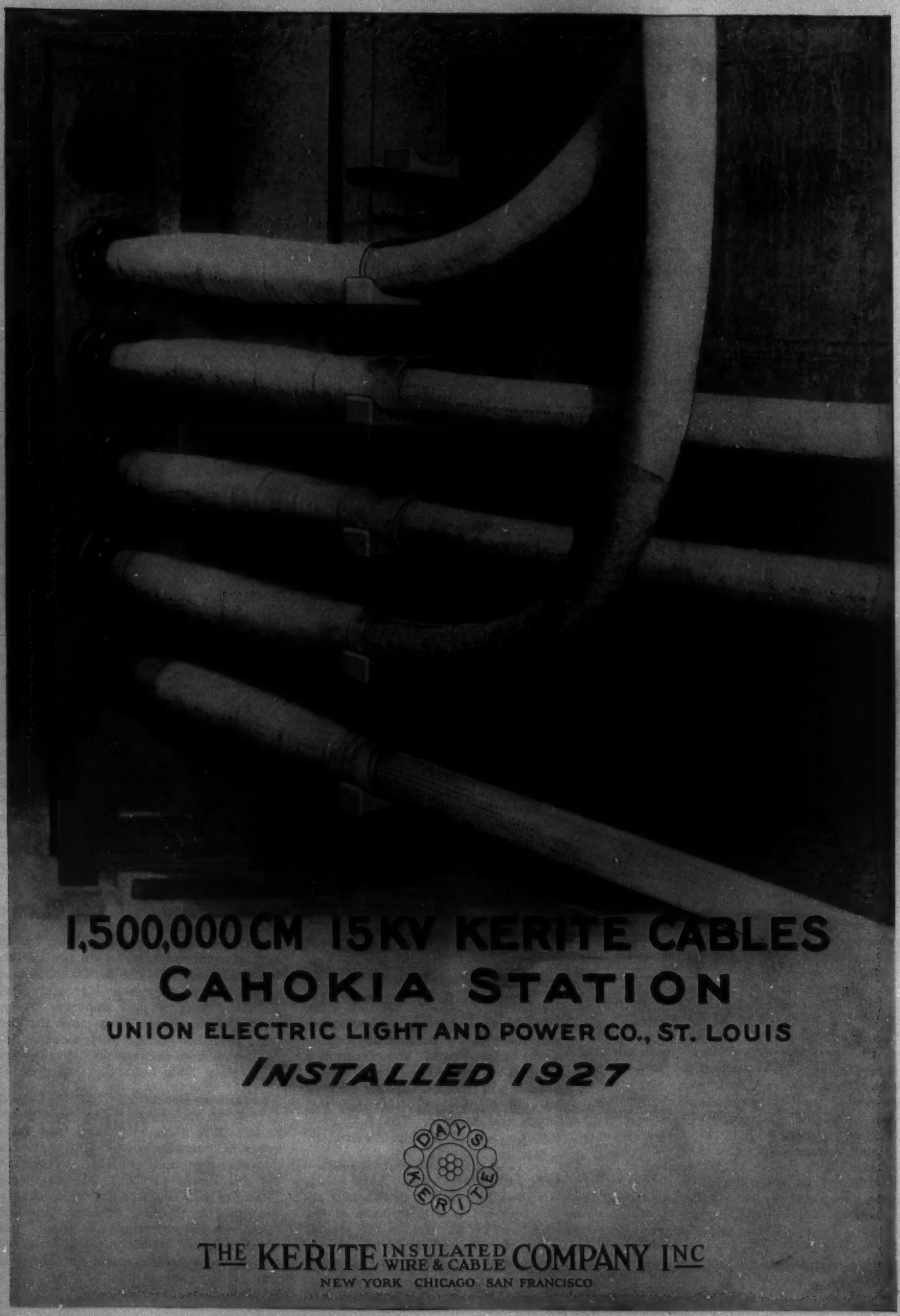
All adjustments of the instrument circuits, amplifiers, potential divider, and current shunts are made initially. Many months of experience has shown that with normal operation the adjustments and the calibration of the instrument system remain quite permanent over long periods of time. The parts which may require re-adjustments are designed to be easily accessible and are equipped, for example, with rheostats, trimmer capacitors, or test connection facilities.

In view of the stable performance of the instrument system, occasional simple routine check tests should suffice to indicate that the instrument system is in order. For this purpose a portable voltmeter calibrated at 480 cycles may be used together with the measured resistance part of a circuit unit to indicate that the light-beam voltmeter, ammeter, and wattmeter read correctly.

The potential divider and current shunt phase angles may be checked and if necessary adjusted with the aid of the analyzer master wattmeter, knowing that the power into an analyzer capacitor unit is negligibly small.

The amplifiers have simple rheostat and capacitor adjustments for matching the amplifier input and output in magnitude and phase angle. The cathode-ray oscillograph mentioned above, connected to a suitably located amplifier test jack, is merely used as a sensitive high-impedance null instrument to adjust the output-input voltage differential to zero.

In regard to maintenance of the rest of the analyzer circuits and units, it simply consists of checking and correcting with the analyzer master instruments any abnormal circuit performance. The conservative design of the elements comprising the circuit units and the low resistance contacts and connecting leads assures that the calibration of these elements remains very stable.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Industrial Notes

Millions for Westinghouse Improvements.—Emphasizing that "no agency alone can prime the business pump," A. W. Robertson, chairman of the board of the Westinghouse Electric & Mfg. Co., announced recently that Westinghouse will "do its share" by spending approximately $12,000,000 on new buildings, new machinery and equipment, and other improvements and repairs in the company's district offices, radio stations, and plants, of which there are twenty-two. That sum, approximately the same as that appropriated for similar projects in 1937, is being spent because of faith that a revival of business is coming, "plus our natural desire to do our part in effecting a return of prosperity and employment," Mr. Robertson said. He pointed out that, although the amounts being spent this year and last were virtually identical, there was an important difference; the 1937 outlay was made to keep up with mounting demands on the company for increased production, whereas this year's appropriations are made principally on faith that business conditions will improve, and on the company's desire to be ready for increased production when it comes.

Royal Electric Appointment.—James P. Dunlap has been appointed chief engineer of the Royal Electric Mfg. Co., Chicago. Mr. Dunlap was formerly design engineer for the Electrical Engineers Equipment Co.

Electrical Design Contest.—Announcement of its fourth annual product design contest has been made by "Electrical Manufacturing" in the June issue of that publication. The contest, which is open to anyone engaged in the design, engineering or manufacture of electrically operated machines, appliances and equipment, closes August 15. Cash awards total one thousand dollars.

"Zeon" Lamp Promotion.—Announcement has been made of the formation in Chicago recently of "Claude Associates," the original members of which are those electric sign manufacturers who are licensed for certain types of lamps and fields of use under the many patents of Claude Paz et Silva of France, the General Electric Company and Claude Neon Lights, Inc., of New York. The purpose of this association is the promotion of the new fluorescent tube lamp which will be known by the trade name of "Zeon." This product is an improvement on the Neon tube lamp, giving up to ten times brighter illumination than the ordinary Neon lamp, yet consuming the same amount of current. It can also be made in a wide range of colors, including whites. Fluorescent powders, treated for heat resistance and specially prepared for each of a broad range of colors, coat the inner surfaces of the new Zeon tubes. These powders, actuated by ultra-violet rays and absorbing them, re-radiate the energy in the longer wave bands of color. Each powder has its own characteristic wave band with which it responds to the ultraviolet, thus forming its own particular color of light emitted.

Nichrome Stocked on Pacific Coast.—A representative stock of high nickel content alloys in various shapes and sizes, particularly Nichrome and Nichrome V, is now available for immediate delivery to the Pacific Coast trade, according to an announcement of the Driver-Harris Co., Harrison, N. J. The warehouse is located at 316 Eleventh St., San Francisco, and the Pacific Coast representative is the Electrical Specialty Co., Ltd., engaged for many years past in serving the electrical manufacturing industry with such products as Bakelite, Mica Insulator and Isolantite. Nichrome stocks will be maintained also in Los Angeles and Seattle.

Trade Literature

Outdoor Switchhouse.—Bulletin L2299, 4 pp. Describes the advantages of metal enclosed switchgear over open type construction; includes dimensions and construction data. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Hardness Testing Equipment.—Bulletin 1, 56 pp. Describes numerous types of testing machines and instruments, including a new direct reading production Brinell machine. Tinius Olsen Testing Machine Co., 500 No. 12th St., Philadelphia, Pa.

Motors.—Bulletin 142, 4 pp. Describes Sterling "Klosd" motors applicable particularly in corrosive atmospheres. Outstanding in the improvements effected is the patented herringbone rotor, made of one-piece cast aluminum. Sterling Electric Motors, Los Angeles, Calif.

Slip-Ring Motors.—Bulletin M-2, 8 pp. Describes convertible slip ring motors, illustrating the standard conversions for four types of service possible with these motors, namely, splash-proof, dust and weather proof, enclosed fan-cooled and standard types. Harnischfeger Corp., 4400 W. National Ave., Milwaukee, Wis.

Battery Charger.—Bulletin RR-100, 4 pp. Describes a new rectifier type battery charger designed for permanent installation under railroad cars. The charger is a complete unit, containing the necessary transformer and rectifier, together with all control equipment in a weather-tight and dustproof steel housing. The B-L Electric Mfg. Co., 19th & Washington Ave., St. Louis, Mo.

Lightning Arresters.—Bulletin LMB 38151, 24 pp. Describes valve type lightning arresters. Included is a description of the "Isolator," which disconnects the ground lead from the arrester instantly, thereby preventing continuous flow of current to ground in case of damage to the arrester. Line Material Co., South Milwaukee, Wis.

Steam Turbines.—Bulletin 1191, 8 pp. Describes one frame size of a complete line of impulse reaction steam turbine generating units. These turbines contain most of the design features used in large 3600-rpm turbines. The frame size illustrated and described in this bulletin has been designed for a capacity range of 1000 to 1500 kw. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Rheostats.—Catalog 17. Describes an extensive line of vitreous enameled close control rheostats, resistors, tap-switches, chokes, non-inductive resistors, line cord resistors, radio-frequency chokes, transmitting band change switches and tap-switches, precision resistors, etc., for the industrial, radio and electronic fields. Ohmite Mfg. Co., 4842 W. Flournoy St., Chicago, Ill.

Motors.—Bulletin GED 664, 12 pp. Farm profits and savings resulting from the use of electric motors on the farm are listed and analyzed in this publication. Every important use for motors on the farm is analyzed in the "summarized data guide chart," which briefly sets forth the type, rating, and power consumption of the motor recommended for performing each of about 70 farm jobs. General Electric Co., Schenectady, N. Y.

Frequency Recorders.—Catalog N-67-161, 20 pp. Describer Micromax frequency recorders and indicators. Includes a discussion of considerations responsible for the increasing use of equipment for frequency measurement and for frequency-load control. Illustrations show modern installations in steam, hydro and diesel plants, large and small, as well as in load dispatchers' offices and in laboratories. Leeds & Northrup Co., 4962 Stenton Ave., Philadelphia, Pa.

Generator Voltage Regulators.—Cat. Sec. 31-260, 12 pp. Describes Silverstat regulators for the automatic voltage control of small a-c and d-c generators. Illustrations include diagrams of construction of main control element, schematic wiring diagrams and outline dimensions. Curves show approximate range of application for control of single constant speed d-c and a-c generators. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Clamps.—Bulletin 641H, 4 pp. Describes a neutral conductor clamp. The pamphlet shows how the clamp can be used for the neutral conductor only, for the neutral conductor and a ground wire, or for the neutral conductor plus service and ground wires. Bulletin 642-H, 4 pp. Describes an improved angle clamp, illustrating the one-piece assembly feature, and showing how the device saves material and labor in turning angles. Ohio Brass Co., Mansfield, O.

Transmitting-Receiving Tubes.—Bulletin 1275-B, 16 pp. Gives characteristics data on all RCA glass, glass-octal, and metal types in numerical-alphabetical sequence. Socket connections with RMA designations are also shown. Bulletin TT-100, 16 pp. Describes RCA air-cooled transmitting types according to triodes, tetrodes, pentodes, rectifiers, and miscellaneous types. The types of special interest to radio amateurs are shown in bold face and are also illustrated. Commercial Engg. Sec., RCA Radiotron Division, Harrison, N. J.

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I-T-E announces the extension of their line of air-break switchgear to include circuit breakers for service on 2500-5000 volt circuits; interrupting capacity up to 150,000 KVA.

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New Products

Phototube Relay Experimental Unit.—A new phototube relay unit, suitable for experimental or research work, for educational problems or lecture demonstrations, has been developed by G-M Laboratories, Inc., Chicago. This phototube relay, known as type 1224A, comprises a phototube, thermionic amplifier, resistor, potentiometer, condenser, and a small electromagnetic relay. The wiring diagram is printed on the base. All wire, terminals, brackets, and screws are included. It is furnished as a kit for student assembly or completely assembled and ready for use. In educational work, the unit serves as a lecture demonstration outfit, as well as for instruction in and study of the photoelectric and thermionic amplifier tubes. It is also adaptable to student problem work in construction and wiring. The research technician can adapt the unit to such work as controlling liquid levels, controlling signals from a pendulum or other moving devices, or starting and stopping apparatus. It is also useful as a limit switch and for simple photometric values.

Thread-Cutting Screws for Plastics.—The Shakeproof Lock Washer Co., 2501 No. Keeler Ave., Chicago, has introduced a new thread-cutting screw for plastic materials. A specially designed double width slot gives an acute cutting edge that cuts a clean, sharp thread in all types of plastic compositions, both molded and laminated. This construction materially reduces the high driving torque normally encountered and enables fast, easy driving with a minimum of the breakage common to molded plastics. Tapping operations or threaded inserts are unnecessary; the screw is simply inserted in a molded or drilled hole of the proper size and driven home with a hand or power driver. A free demonstration kit of Shakeproof "Hi-Hook" thread-cutting screws, including an assortment of different sizes and complete instructions for testing can be had by writing the company.

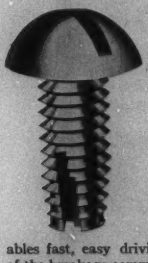
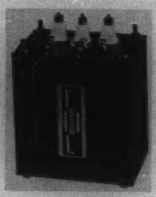


Plate and Filament Transformers.—Ferranti Electric, Inc., 30 Rockefeller Plaza, New York City, has introduced a complete new line of low cost plate and filament transformers for the electronic field. Stock transformers are available up to 200 va and the line is comprised of three separate groups: series of plate-filament transformers for use in conjunction with all the latest tubes; a group of filament transformers, and a group of filter reactors. This last group is unique in that each reactor is double wound so that it may be connected in series or parallel, thus obtaining either of two different values of inductance and current in the same unit. All components are supplied in the new, Ferranti through type, completely reversible case, which enables the unit to be either top- or sub-panel mounted. The cases are of folded steel with heavy solder lug or porcelain terminals.



Visible Enclosed Switch.—The I-T-E Circuit Breaker Co., 19th & Hamilton Sts., Philadelphia, offers a new combined, enclosed disconnect switch and circuit breaker for heavy mill service. A window of shatter-proof glass permits the operator to actually see the opening of the disconnect contacts, assuring safety at all times. The standard blade type disconnect switch ahead of the circuit breaker is manually operated by a lever on the right hand side of the enclosure. The disconnect and the circuit breaker are interlocked so that the switch cannot be opened or closed while the circuit breaker is closed. The circuit breaker itself is an electrically operated, remote controlled device of the "K" type. The "K" type circuit breaker has been designed to give modified contactor service and at the same time high interrupting capacity and high speed in operation.

Fiber-Glass Insulated Magnet Wire.—A new Deltabeston magnet wire, insulated with fiber glass, has been announced by the General Electric Co., Bridgeport, Conn., as an addition to the present line of Deltabeston asbestos-insulated magnet wire. Deltabeston glass-insulated magnet wire, like Deltabeston asbestos-insulated magnet wire, is available in round, square, and rectangular shapes.

Employment Bulletin

Engineering Societies Employment Service

MAINTAINED for their members by the national societies of civil, mining, mechanical, and electrical engineers, in co-operation with other organizations. An inquiry to any of the three offices will bring full information.

A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

In the interest of effective service, it is essential that members using the employment service keep the bureau office serving them advised at reasonable intervals concerning their availability for employment, concerning any change in status, and immediately upon acceptance of any employment.

Employers interested in the following announcements should address replies to the key numbers indicated, and mail to the New York office.

Men Available

E.E., B.S., 1936, single, 24; 2 yrs exper in des and inspection of high voltage transm and primary distr lines. Location immaterial. Employed. Desires better opportunity. E-248.

E.E., 40, single; 8 yrs util exper including des, constr overhead and underground systems; one yr on inventory appraisal. Desires pos any field or rural electrification. Location immaterial. Available immed. E-254-2684-Chicago.

E.E., 39, with 13 yrs exper as elec des engr for elec util system; 10 mos with large elec contracting firm as contracting engr. Location immaterial. E-255.

B.S.E.E., '32, M.S.E.E. '33, Purdue; 28, married; 18 mos exper draftg, layout and des of paper making machy; 18 mos exper as asst devpmt engr large elec co. Surveying exper. Middlewest preferred. E-259.

B.S.E.E., Worcester Poly, '35; 3 yrs des and draftg machine tool industry; 25, single. Desires pos elec industry pwr co preferred. Any good elec opening considered. E-258.

E.E., 38, married; 12 yrs draftg, des, devpmt, constr, instal, service, control signal circuits, electronic devices, pwr plants, suostations, U. S., Latin Am. Includes 7 yrs on electronic sound eqpt and several yrs on automatic control. E-247-8-C-7-San Francisco.

E.E., B.S., 39, married, 2 children; 12 yrs plant extension; 3 yrs budget and admiaistrative work. Available on reasonable notice. E-245.

REGISTERED E.E., univ grad, 15 yrs mfg exper des and application of control and electromagnetic devices; 14 yrs elec supt large indus plant having 2 pwr plants, motor winding shop. E-246.

EXEC ENGR, MIT postgrad, 41, exper in research, devpmt, pwr house and substation constr, des, maintenance and oprn of large installations. Location immaterial. Available on short notice E-253.

E.E., B.S., 1937, 22, married; 9 mos exper in tel work. Interested in com engg. Location immaterial. E-249.

B.E.E., M.E.E., recent grad, single, 23. Available immed. Location immaterial. E-250.

E.E., M.S., 1935, Univ Mich, Tau Beta Pi, 26, married. Postgrad study: Electronics. One yr distr oprn; one yr elec substation des. Middlewest or East. Desires: Pub util, research, teaching. E-251.

B.E., 1937, single, 24; 2 yrs student asst instructor in E.E. Exper as draftsman for elec contractor. Student engr with elec util. Desires pos offering exper and advancement. Location immaterial. E-256.

E.E., B.S., 1937 and B.S. (physics), single, 25. Westinghouse grad student with exper in tube des and mfg, radio des, devpmt tube control circuits. Desires pos with allied mfg concern. E-260.

AIRCRAFT E.E., B.S., Cooper Union, 35., Honor soc. Exper remote indicating instruments pwr supply, small motors, generators, dynamotors, "choppers," vibrators. Studied vibration absorption. Field exper aircraft wiring, automatic controls. Prefers sales, contact engg. E-252.

PROF, B.S.E.E., 39, GE Test and Engg Dept 3 yrs; elec util 5 yrs; teaching 10 yrs; married; conscientious, dependable. Employed but present pos unsatisfactory. E-257.

E.E., 35, G.E. test, supt of small shop; field constr, instal and service; des and draftg. Desires supervisory pos in Phila, NY Area. Available immed. E-244.

E.E., B.S.; 10 yrs exper on devpmt and des of small elec apparatus; relays, transformers, rectifiers. Alert, persistent, precise. Prefers pos with elec mfg co in Middlewest. E-264.

Continued on p. 10

Perfect INSULATING COMPOUNDS

for a wide range of temperature

Cable Joint and Pothead Compounds with service records of many years standing. They show all the physical and electrical characteristics necessary for insulating materials of this class.

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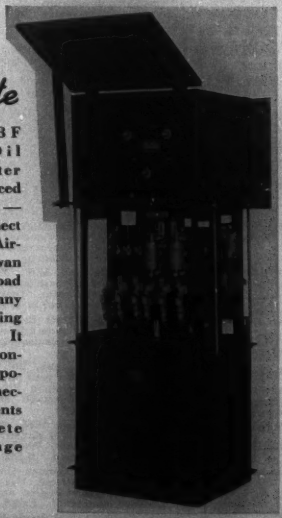
It's Complete

Type 900 KBF Combination Oil Immersed Starter includes: reduced voltage starting — Safety Disconnect Switch—Rowan Air-Seal Fuses—Rowan Magnetic Overload Relays—and many other outstanding Rowan features. It is, in fact, a control unit incorporating all the necessary requirements of a complete reduced voltage starter.



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The only tool you need is a hammer

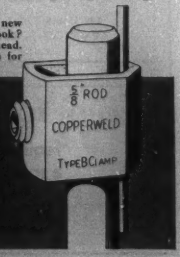
NO special driving tools are needed with Copperweld Ground Rods. Your men can easily drive even the smaller sizes—such as half-inch by eight foot—without the rods bending. The rigid core of special steel takes care of that.

Labor costs are lower with Copperweld Rods, and losses from scrapping bent or deformed rods are practically nil.

Because the top ends of all Copperweld rods are chamfered to reduce "mushrooming" after driving, the clamps may be slipped over the tops of the rods *after driving*.

And Copperweld Type B Clamps provide the simplest, most dependable and economical means of connecting the grounding wire to the rod.

Have you received your copy of the new Copperweld Ground Rod and Clamp Data Book? If not, just ask for it on your company letterhead. Specify Copperweld Ground Rods and Clamps for economy and dependability.



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Employment Bulletin

Continued from page 8

A BRIGHT, ORDERLY YOUNG MAN, with excellent tech background and exper, desires an elec engg pos with some reliable concern where he can freely express his talents in des. E-267.

ELEC ENGR, Doctor's deg, foreign univ grad; 15 yrs exper with protective devices, high voltage distr systems, Petersen coil application. Specialist on earth fault problems and neutral point grounding. E-261.

ELEC ENGR, 25 yrs exper, indus, util, contracting, sales. In charge des, constr, maintenance large projects. NJ license. E-268.

E.E., single, 24, recent grad desires connection pub util or elec mfg co East, Middlewest. Willing to travel and leave country; So. Am. preferred. Hard worker; excellent ref. E-262.

E.E., B.S., Ga Tech, 1936, single, 25. Tau Beta Pi; 2 yrs WEMCO student and district sales; 2 yrs elec apprentice; 3 mos generator constr. Available immed. Domestic or foreign. E-263.

E.E., B.S., age 23, Tau Beta Pi; 15 mos lab and devpmt work, calibration and maintenance of testg eqpt; 11 mos des of air conditioning, heating and cooling systems. E-265.

B.S.E.E., Univ of Minn, '37, 23, single; Tau Beta Pi, Eta Kappa Nu. G.E. test. Desires pos in elec engg field. Location immaterial. Now employed. E-266.

M.S. in E.E., '38, honor student, Tau Beta Pi, Sigma Xi; available for electronic or allied fields; devpmt, research, prod. Bell Lab exper. Analytical ability, exec possibilities. E-269.

E.E., B.S., June 1937, Univ of N.C. Test exper on pwr transf, radio transmitters; research and devpmt on indus control apparatus. Desires elec engg research pos. E-272.

B.E.E., Jan. '38, age 24. Practical and theoretical training in elec engg and surveying; good draftsman; 2 yrs exper testg motors. Desires pos in any field. Foreign languages: Italian, French. E-273.

B.S., E.E., '37, single; desires pos office or field in elec constr; one yr testg, inspection, high and low tension eqpt, swbd wiring, protective devices on substation during constr. Location immaterial. E-275.

B.E.E., 26, married; 3 yrs Diesel-electric maintenance. Employed. Desires pos in teaching or any indus pos that will allow some leisure time to pursue advanced studies leading to Master's deg. E-270.

B.S.E.E., 1933, 29, married. Continued study engg, economics; 9 yrs utilities: Pwr, com. Eqpt devpmt, specifications, inspection testg, mfg methods, reports, pub relations. Desires pos with mfr: engg, prod or sales. E-276.

E.E., B.S., 1930. G.E. test; mfg engg exper. Desires pos in application or central station engg with pub util or a concern mfg elec eqpt. E-277.

GRAD E.E., 1930; 3 yrs pub util engg; 4 yrs bldg constr supervision; 7 yrs evening and one yr day sch teaching engg subjects. Ambition and initiative. E-271.

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B.S.E.E., 1934, single, 26, Westinghouse Test Course grad. Exper in engg and commercial testg of all lines of elec apparatus. Desires pos with pub util. Location immaterial. E-278.

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B.E.E., '38, Pratt Inst, desires pos with elec mfr or util. Part time sales and maintenance work vacations. Available immed. Location, East preferred. E-280.

E.E., B.S. Rutgers, '36, DeForest's Training, married, 24; exper prod loud speakers. Was test set repairman Western Elec; also exper safety engr. Prefers responsible pos Met. NY or northern NJ. E-281.

PENN STATE, 1934, married, 25; one yr electrician; 1½ yrs statistician; one yr outdoor substation inspector. Desires pos as engr with pub util or indus concern. E-282.

E.E. GRAD, German Univ, 1935, 26, single; 2 yrs exper testg transf; 1½ yrs practical training; now employed. Desires des or research work. Location immaterial. E-283.

E.E., 1921. Prof license NJ; 4 yrs indus engr, estimates, reports, des, devpmt; 11 yrs des engr, central station and substation. Foreign language German. E-284.

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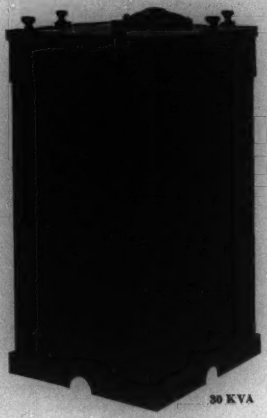

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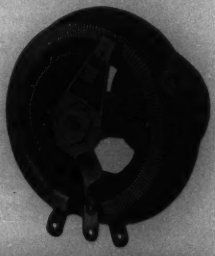

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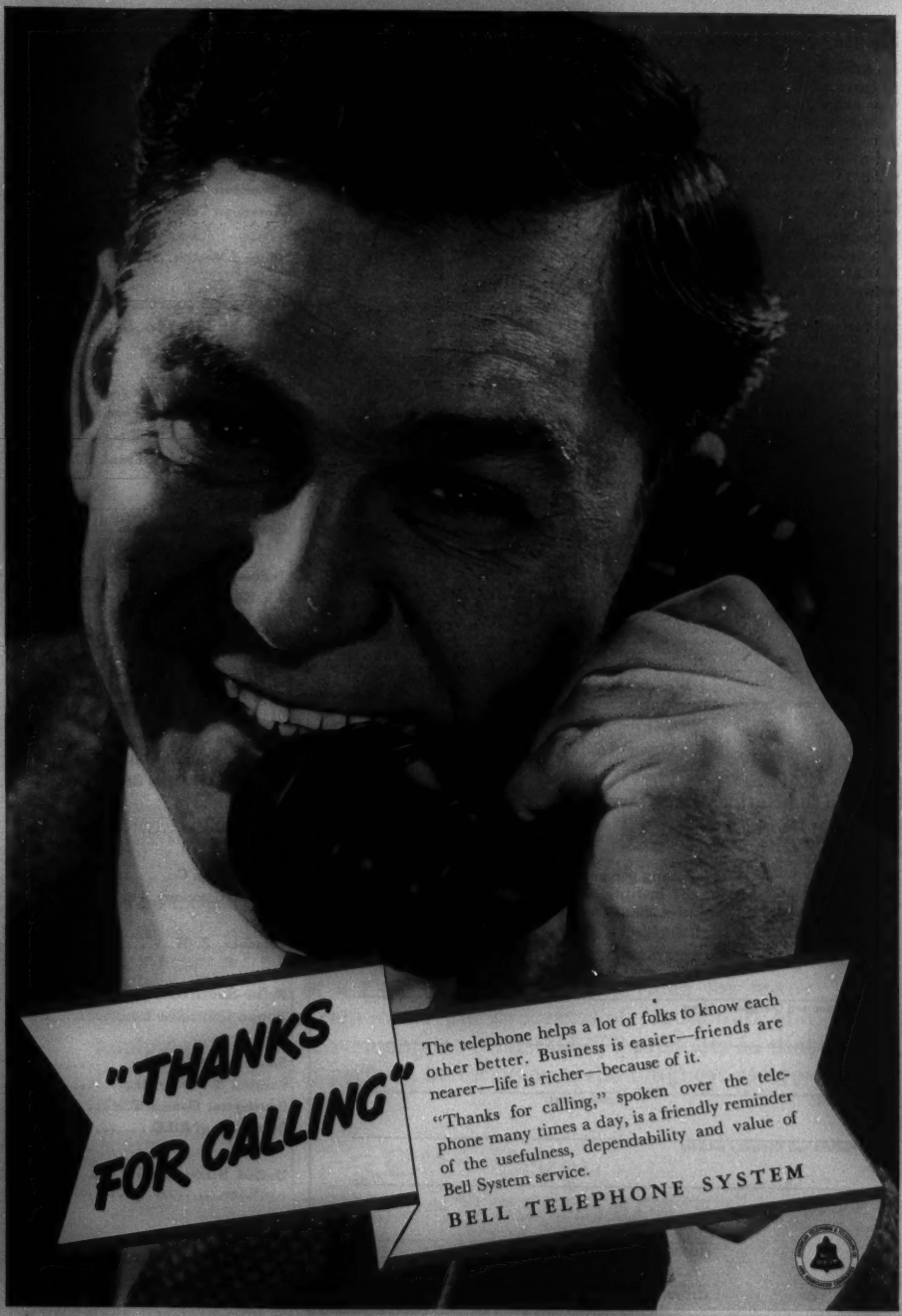
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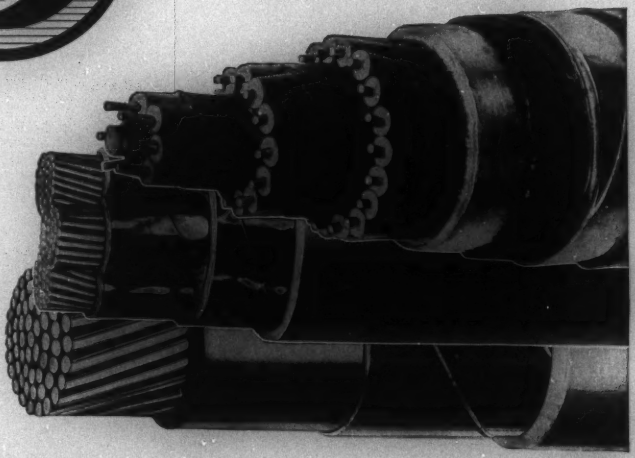

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